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MINISTRY OF ENERGY AND WATER

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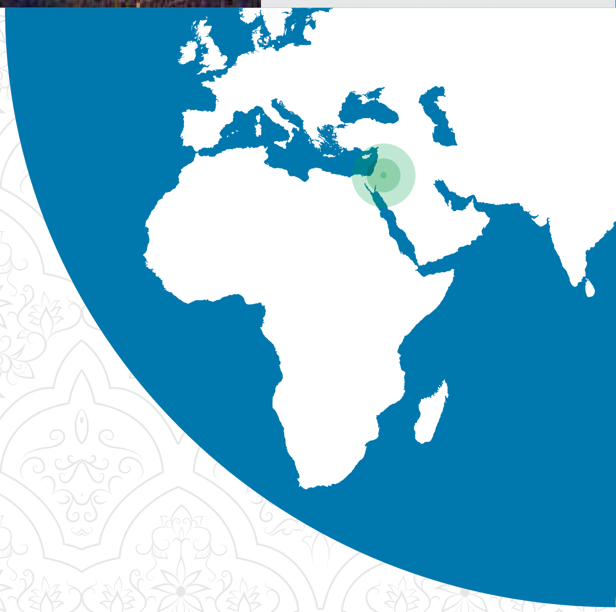

RENEWABLE ENERGY OUTLOOK

LEBANON

Based on Renewables Readiness Assessment and REmap analysis

JUNE 2020

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About IRENA

The International Renewable Energy Agency (IRENA) serves as the principal platform for international co-operation, a centre of excellence, a repository of policy, technology, resource and financial knowledge, and a driver of action on the ground to advance the transformation of the global energy system. An intergovernmental organisation established in 2011, IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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RENEWABLE ENERGY OUTLOOK

LEBANON

FOREWORD
from the Minister of Energy and Water

While Lebanon assesses its progress towards the target of 12% renewable energy in 2020, the Ministry of Energy and Water has mobilised stakeholders nationwide to set new objectives for the next decade. This Renewable Energy Outlook report comes at the ideal moment to help set up a clear and well-designed roadmap, specifically for Lebanon to reach new horizons in renewable energy development by 2030.

Thanks to the efforts of the International Renewable Energy Agency (IRENA), and with the involvement of numerous national and international stakeholders, this report presents the Renewables Readiness Assessment (RRA) and Renewable Energy Roadmap (REmap) country analysis of Lebanon. In doing so, the report pinpoints challenges and barriers, showcases success stories and achievements, and most importantly proposes solutions and measures to move forward to an ambitious REmap scenario whereby 30% of Lebanon's electricity mix would be renewable energy by 2030.

Allow me to thank all the IRENA team members who contributed to the realisation of this report. I am also grateful to all the representatives and stakeholders involved. The work invested in developing this report will have a positive impact on Lebanon's sustainable energy transition for years to come, thus contributing to the grand energy transition that IRENA is striving to achieve in all parts of the world.

On behalf of the Ministry of Energy and Water, I would like to confirm Lebanon's determination to use this outlook in shaping our future action plans. Undoubtedly, we will use the contents of this report in developing the next National Renewable Energy Action Plan for Lebanon, covering the period 2021-2025. While the renewable energy market in Lebanon has witnessed considerable advancements in the past ten years, we are now more determined than ever to step up investment efforts for a better, more sustainable, future.

I am fully aware that to achieve all these promising targets, a strong partnership between the public and private sectors is needed. We are also eager to work with international friends and partners to make renewable energy a main pillar of the Lebanese energy sector. Together, we will make this happen.

Raymond Ghajar
Minister of Energy and Water
Lebanese Republic

FOREWORD
from the IRENA Director-General

Along with the rest of the world, Lebanon has confronted an unexpected, and in many ways unprecedented, combination of health and economic shocks in 2020. While the COVID-19 pandemic has brought grief and hardship, the need to respond quickly and effectively has underlined the value of close, transparent co-ordination. Beyond short-term recovery measures, the country and its people need to focus their efforts together on longer-term improvements, including ensuring energy security and building a resilient economy.

As the country moves forward, renewable energy technologies offer the prospect of stable, clean power and heat systems. Along with other Middle Eastern net energy importers, Lebanon has faced a widening gap between the supply and consumption of electricity in recent years. Economic development and population growth have pushed its existing power infrastructure to the limit. An increasingly renewable-based system, in contrast, would mean reliable domestic power services, sufficient to match growing demand and consistent with global climate goals.

To prepare for future needs, Lebanon has set out to diversify its energy mix. This started with national action plans to scale up renewables and improve energy efficiency in 2016-2020, with an initial target for solar, wind, bioenergy and hydropower to cover some 12% of primary energy consumption. With small-scale renewable applications gaining ground, more recent plans have raised the target to 30% renewable energy consumption, spanning both electricity and heat demand, by 2030.

Renewable Energy Outlook: Lebanon, prepared in collaboration with the Ministry of Energy and Water (MEW) and the Lebanese Center for Energy Conservation (LCEC), identifies key challenges as the country pursues environmentally and economically sustainable power and heat. The report highlights the policy, regulatory, financial and capacity-building actions needed to meet or surpass current targets. It combines the results of country-led stakeholder consultations with a comprehensive roadmap to maximise the deployment of renewables through 2030.

Through an updated, sustainability-focused energy policy, Lebanon could achieve 30% renewable electricity consumption by 2030, saving nearly USD 250 million per year in the power sector, mainly through avoided fossil-fuel imports. Electricity services, which until now have added to the deficit, could instead ease the government's debt load. Recent tenders for renewable power have attracted strong international interest, and Lebanon's resolve to take this vision forward remains firm.

IRENA wishes to thank the MEW and LCEC teams for their key input and engagement. We also appreciate the valuable contributions of numerous other stakeholders and international partners. I sincerely hope the resulting study helps to accelerate Lebanon's shift to a sustainable energy future.

Francesco La Camera
Director-General
International Renewable Energy Agency

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ABBREVIATION

AMI	advanced metering infrastructure
AUB	American University of Beirut
bbl	barrel (of oil)
BDL	Banque du Liban (Lebanon's central bank)
BRSS	Beirut River Solar Snake
CAGR	Compound annual growth rate
CAPEX	capital expenditure
CCGT	combined-cycle gas turbine
CCPP	combined-cycle power plant
CDR	Council for Development and Reconstruction
CoM	Council of Ministers
COP	coefficient of performance
CSP	concentrated solar power
DO	diesel oil
DREG	decentralised renewable energy generation
DSP	distribution service provider
EBRD	European Bank for Reconstruction and Development
EPC	engineering, procurement and construction
ESMAP	Energy Sector Management Assistance Programme
EDL	Electricité du Liban (national power utility)
EDZ	Electricité de Zahle (city power utility)
EOI	expression of interest
ERA	Electricity Regulatory Authority
EV	electric vehicle
GDP	gross domestic product
GHI	global horizontal irradiance
GT	gas turbine
HFO	heavy fuel oil
IFI	International Financial Institutions
INDC	Intended nationally determined contributions
IPP	Independent power producer
IRENA	International Renewable Energy Agency
ktoe	Thousand tonnes of oil equivalent
LCEC	Lebanese Centre for Energy Conservation
LCB	Lebanese commercial banks
LCRP	Lebanon Crisis Response Plan
LCOE	Levelised cost of electricity
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
LRA	Litani River Authority
MEW	Ministry of Energy and Water

MoF	Ministry of Finance
MSW	Municipal solid waste
MW	megawatt
MT	million tonnes
NEEAP	National Energy Efficiency Action Plan
NEEREA	National Energy Efficiency and Renewable Energy Action program
NREAP	National Renewable Energy Action Plan
OCGT	open cycle gas turbine
OECD	Organisation for Economic Co-operation and Development
OPEX	operational expenditure
O&M	operation and maintenance
P2P	peer-to-peer
pKm	passenger kilometre
PJ	petajoules
PPA	power purchase agreement
PPP	public–private partnership
PPMA	Public Procurement Management Administration
PV	photovoltaic
REmap	IRENA roadmap for scaling-up renewables
RES	renewable energy systems
RFP	request for proposal
RRA	Renewables Readiness Assessment (IRENA)
SWH	solar water heater
TFEC	total final energy consumption
T&D	transmission and distribution
TPES	total primary energy supply
TSO	transmission system operator
UNDP	United Nations Development Programme
WACC	weighted average cost of capital


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EXECUTIVE SUMMARY

Energy and electricity demand have weighed heavily on the Lebanese economy in recent years. Imported fuel oil alone accounts for nearly a quarter of the national budget deficit. Population growth has pushed energy use up steadily, with the demand for power increasingly exceeding existing generationcapacity.

While private producers have helped to close the gap, such arrangements are costly for both consumers and the national utility, Electricité du Liban (EDL). Renewable energy technologies, in contrast, promise stable, clean, fully domestic power and heat systems. Amid the coronavirus (COVID-19) outbreak in early 2020, renewables and energy efficiency have become a key part of the country's recovery plans.

Lebanon currently relies on gasoline, fuel oil and gas oil, which are 100% imported. Energy security concerns, combined the need to support economic growth, have driven an energy diversification strategy.

This strategy was outlined in two updates to a key electricity reform paper: the first in 2010, which further led to the National Energy Efficiency Action Plan (NEEAP) in 2011 and the National Renewable Energy Action Plan (NREAP) for 2016–2020; and the second producing the NEEAP for 2016-2020.

These action plans build on the high availability of renewable energy sources and the potential for the deployment of renewable energy and energy efficiency measures to satisfy 12% of primary energy consumption for both electricity generation and heating purposes by 2020.

Lebanon's commitment to scaling-up the use of renewable energy technologies is fortified by ongoing updates to its renewable energy targets. A new target aiming to meet 30% of total primary energy consumption (electricity and heating demand) from renewables by 2030 was introduced in 2018 and formed the basis of a first update to the electricity reform paper in March 2019. To date, total installed renewable energy power capacity amounts to 350 megawatts (MW), including 286 MW from hydropower sources, 7 MW from landfill and 56.37 MW from solar power. Therefore, additional measures are required to scale-up renewables to the level of 30% by 2030 as defined in this study's REmap case.

Lebanon has ample renewable energy resources that may be utilised to achieve these targets, including both solar and wind potential. An action plan to guide the development of these resources has been produced by the Lebanese Centre for Energy Conservation (LCEC) – the technical arm of the Ministry of Energy and Water.

One outcome of the plan (under initiative 11) is to create the National Energy Efficiency and Renewable Energy Action (NEEREA) initiative. Developed in collaboration with the central bank of Lebanon (BDL), this facilitates the provision of low interest rate loans for all renewable energy applications and energy efficiency projects, with a loan ceiling of USD 10 million per project and a maximum term of 14 years – including a grace period of between six months and four years.

Despite the challenges facing the energy sector in terms of grid infrastructure, this national financing scheme, designed to incentivise the market, has achieved remarkable success. Having financed more than 938 projects as of March 2019 it also signals the commitment and interest of both the public and private sectors to the deployment of renewable energy projects. In terms of large-scale projects, Lebanon signed its first power purchase agreement (PPA) for electricity consumption from renewables in 2018, with a total capacity of 226 MW.

However, the success of these schemes has been overshadowed by several factors including the current policy, legal and institutional framework governing large-scale projects, and a lack of awareness of support schemes provided at the small-scale level, as highlighted in the Renewables Readiness Assessment (RRA) study.

This study, which was done by the International Renewable Energy Agency (IRENA) in collaboration with Lebanon's Ministry of Energy and Water (MEW) and the LCEC, provides an in-depth assessment of the policy, regulatory, financial and capacity challenges that must be overcome to achieve the targets set out for 2030. In this context, the RRA methodology seeks to facilitate country-led consultations with multiple stakeholders, identify key challenges and highlight solutions to boost renewable energy deployment. It also provides an in-depth analysis based on the Renewable Energy Roadmap (REmap) analysis approach, identifying additional renewable energy potential and quantifying other factors such as costs, investment needs, and effects on externalities related to air pollution and the environment.

Based on IRENA's REmap analysis, Lebanon has the potential to supply 30% of its electricity mix from renewables by 2030. This amounts to doubling the share of renewable energy expected from existing plans and policies (the reference case scenario) and achieving a 10-fold increase on the roughly 3% rise recorded in 2014 (the base year of this analysis). This assessment utilises the updated targets and most recent electricity reform paper released in 2019. With renewable power, heat and fuels all factored in, renewable energy could provide around 10% of Lebanon's total final energy supply in 2030, up from less than 1% overall in 2014.

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With renewable power, heat and fuels all factored in, renewable energy could provide around 10% of Lebanon's total final energy supply in 2030, up from less than 1% overall in 2014.

The REmap analysis also finds that due to the declining costs of renewable power technologies, their increased deployment could result in potential average savings in the power sector of USD 249 million per year under an average case scenario when compared with the reference case. This is true even before factoring in the reduction in external costs from air pollution and CO_2 emissions. Investment in renewable energy capacity in the power sector, in comparison to the reference case (i.e. the additional amount needed), is estimated at around USD 2.2 billion. While these costs do not include the infrastructure upgrades required to implement the REmap options, their advantages are not limited to the reduction of costs and emissions but also offer broader socio-economic advantages and global benefits such as the creation of new jobs and markets, the injection of cash inflows, and improved energy security through the diversification of the energy mix.

Therefore, the successful realisation of such deployment would require major adjustments to policy, regulatory, technology, infrastructure and financing mechanisms. The current framework in place does not fully account for the rapid economic and technological changes taking place at the national and regional levels. This assessment finds that several key challenges would need to be addressed to further overcome the present energy crisis. Therefore, the following recommendations will allow Lebanon to meet – and, in due course, exceed – the existing targets in the NREAP.


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1. Implement more stable and integrated regulations for renewable energy deployment

Despite Lebanon's ambitious renewable energy strategy, the NREAP has not translated into reality on the ground owing to the instability of the regulatory framework governing the energy sector.

Law 462, adopted in 2002, paved the way for renewable energy sector privatisation in Lebanon and established the Electricity Regulatory Authority (ERA) to grant licenses for utility-scale applications.

Law 462 was side-lined by Law 288 of 2014, which indicated that the Council of Ministers (CoM) and upon the recommendations of the MEW and Ministry of Finance (MoF) would license Independent Power Producers (IPPs). The existence of several laws of conflicting dispositions is not conducive to private sector investment in renewable energy projects.

- **Establish the Electricity Regulatory Authority**

  As per the provisions of law 462/2002, creating the Electricity Regulatory Authority (ERA) may provide a clear and single access point to the electricity sector for private companies. With clearly defined licensing procedures, the roles and scope of existing entities will also become clearer, including the LCEC, MEW, EDL, the Public Procurement Management Administration (PPMA), the Higher Council for Privatisation and the CoM.

  In the long term, to better meet the REmap target of supplying 30% of electricity generation using renewables, and in line with the latest announced targets, IRENA suggests including all energy-related laws under an overarching amended law. Thus, overruling any discrepancies or overlaps that exist between them.

2. Adopt new measures for small-scale applications

Net metering was applied in Lebanon following a decision of the Board of Directors of EDL. However, this is bound by the limitations of the industrial and commercial sectors. While at the municipality level, there is a lack of streamlined procedures and awareness among the local authorities and the general public about project implementation. Additionally, off-site installation or power wheeling and peer-to-peer energy exchange limit the possibilities for wider deployment of small-scale applications.

- **Integrate innovative market schemes**

  PPAs that allow developers to sell electricity directly to specific consumers could in turn open the way for peer-to-peer contracts. The REmap analysis finds that technological advancements in the areas of peer-to-peer trading and blockchain may promote the implementation of community-scale renewable energy systems which, in turn, can boost the number of small-scale decentralised solar PV systems in Lebanon. In fact, the market for this type of application is already opening up in the country with the recent implementation of community-based net metering pilot projects that rely on hybrid solar PV systems.

- **Reinstate incentives for the installation of solar water heaters and small-scale applications**

  Among renewable energy applications, solar water heaters (SWHs) were the first to be introduced to the Lebanese market under the NREAP/NEEAP for 2011-2015. Installed SWH collector areas amounted to 669 291 square metres (sqm) by the end of 2018, (LCEC, 2019c) with an immediate target to deploy 1 054 000 sqm by the end of 2020. The successful implementation of SWHs in Lebanon has largely been due to favourable NEEREA loans and cash-back applications, which slowed in 2015. IRENA's REmap analysis finds that subsidising the price of heat pumps to increase competitiveness through financing with international grants will result in additional cost reductions.

3. Complement national targets with technology-specific renewable energy targets

In 2018, Lebanon updated its renewable energy targets with the aim of raising the contribution of renewables in the electricity consumption mix to 30%. However, there is no clarity concerning the contributions of different renewable energy technologies or the split between sectors.

Therefore, the REmap analysis complements the 30% target by defining the individual target capacities for each technology: 1 000 MW of wind; 601 MW of hydro; 2 500 MW of centralised solar PV; 500 MW of decentralised solar PV; and 13 MW of biogas.

IRENA's analyses on target-setting recommends setting sectoral objectives that combine energy efficiency and renewable energy deployments. This reinforces the government's commitment to the scale-up of renewable energy technologies and ensures a private market supported by concrete government action plans.

4. Set enabling tools for the installation of heating and cooling

To date, national efforts to deploy renewables have largely centred around power – rather than heating and cooling applications that focus on SWHs.

According to REmap analyses, setting subsidies for heat pumps to increase competitiveness and complement current SWH incentives may support the introduction of the tools required to improve the uptake of renewables in Lebanon's heating and cooling sector. Furthermore, establishing a databank on application and current market status with tailored support programs may incentivise investments.

5. Reform the current market framework to increase investments and project bankability

Electricity in Lebanon is highly subsidised. Therefore, increasing tariffs and reducing electricity subsidies may encourage public and private investments in renewable energy projects and allow for the proliferation of renewables through small- and medium-scale deployment.

6. Reinforce the grid and conduct grid impact assessments

Despite ample renewable energy potential in Lebanon, the grid is subject to major technical and non-technical losses, amounting to 21% in 2018. Therefore, renewable energy projects – particularly large-scale projects – face significant difficulties. Several studies conducted by regional and international organisations have identified inconsistencies in the frequency readings of the grid. IRENA's REmap analysis finds that the 30% target can be reached if the stability of the system is preserved.

• Reinforce the transmission grid

The updated policy paper for the electricity sector considers a compound annual growth rate (CAGR) of 3% coupled with a drop of 8% in total energy demand assumed in 2020 after the expected tariff increase. The REmap analysis finds that significant improvements to the transmission and distribution network may help meet electricity sector demand through expansion in installed capacity of grid-integrated renewables. Furthermore, increasing interconnection capacity by signing agreements to ease energy flow may facilitate higher levels of penetration of renewables and guarantee grid stability.

• Conduct a complete grid impact assessment

As highlighted in the REmap analysis, dynamic stability measures may assist in mitigating grid challenges such as power and frequency fluctuations. These may include the introduction of electricity storage systems close to renewable energy farms leading to multiple benefits, including enhanced grid stability and addressing curtailment concerns. In addition, IRENA's 2017 study, *Planning for the renewable future*, suggests conducting specialised system studies on the renewable carrying capacity of the Lebanese transmission and distribution grid in different geographical zones, as well as a long-term generation adequacy studies. These exercises may help EDL to develop a realistic valuation of the potential of renewables to meet national power demand.

7. Financing and the role of the private sector

Several incentives have been deployed in Lebanon to provide renewable energy finance, including the NEEREA, the Lebanon Energy Efficiency and Renewable Energy Finance Facility (LEEREFF) and the Green Economy Financing Facility (GEFF) loans that have helped promote distributed PV markets, coupled with financial incentives in the SWH market. However, weak risk allocation due to political instability; grid, resource and off-taker risk; and burdensome administrative schemes must all be addressed for both large-scale and small-scale applications.

- **Streamline administrative processes**

  EDL bankability constitutes a major challenge due to low tariffs and high subsidies, reflecting strong off-taker risk. In the first PPAs for the 226 MW Hawa Akkar wind project, the MEW was the main signatory, while EDL was provided access through a letter of credit signed by the central bank of Lebanon. Therefore, the adoption of a more permanent structure to address the creditworthiness of EDL may allow for better access to different guarantees. In this context, IRENA's open solar contracts produced in collaboration with the Terawatt Initiative can be used to develop standardised country context templates.

- **Develop risk mitigation schemes specific to renewable energy projects by IFIs**

  Limited access to guarantees from the MoF or private guarantors constrains developers' access to viable financing.

  Considerable areas of land in regions with the highest solar and wind potential have unclear ownership licenses, resulting in major challenges for project developers that are responsible for land acquisition, whilst also increasing associated risks and costs.

  Risk mitigation instruments are not always easy to identify or obtain. IRENA's online matchmaking service – offered through the Climate Investment Platform (CIP) – can be used to identify developers, lenders and investors. With suitable instruments, IFIs can move from issuing concessionary loans to providing blended finance (public–private co-financing trades) and risk mitigation solutions to mobilise the local private sector.

Areas with high solar and wind potential face licensing challenges

Photograph: Shutterstock

I. INTRODUCTION

Country Background

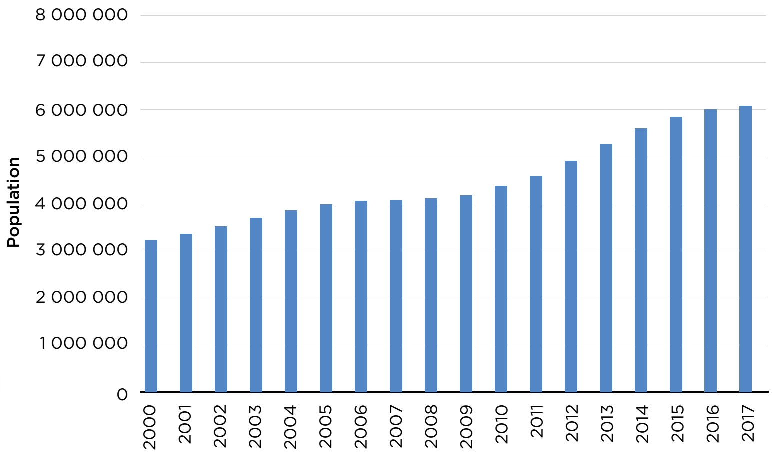
Geography

The Lebanese Republic is a sovereign state located in Western Asia adjoining the eastern edge of the Mediterranean region from the south along a 79 km border. It has a total territory of 10 452 km2, with a 225 km coast along the Mediterranean Sea that features a narrow coastal plain that is 6.5 km at its widest point and lies below the Lebanon Mountains, which rise to a maximum elevation of 3 088 meters. The Bekaa Valley separates the Lebanon and Anti-Lebanon Mountains, with the latter rising to 2 814 m.

Demographics

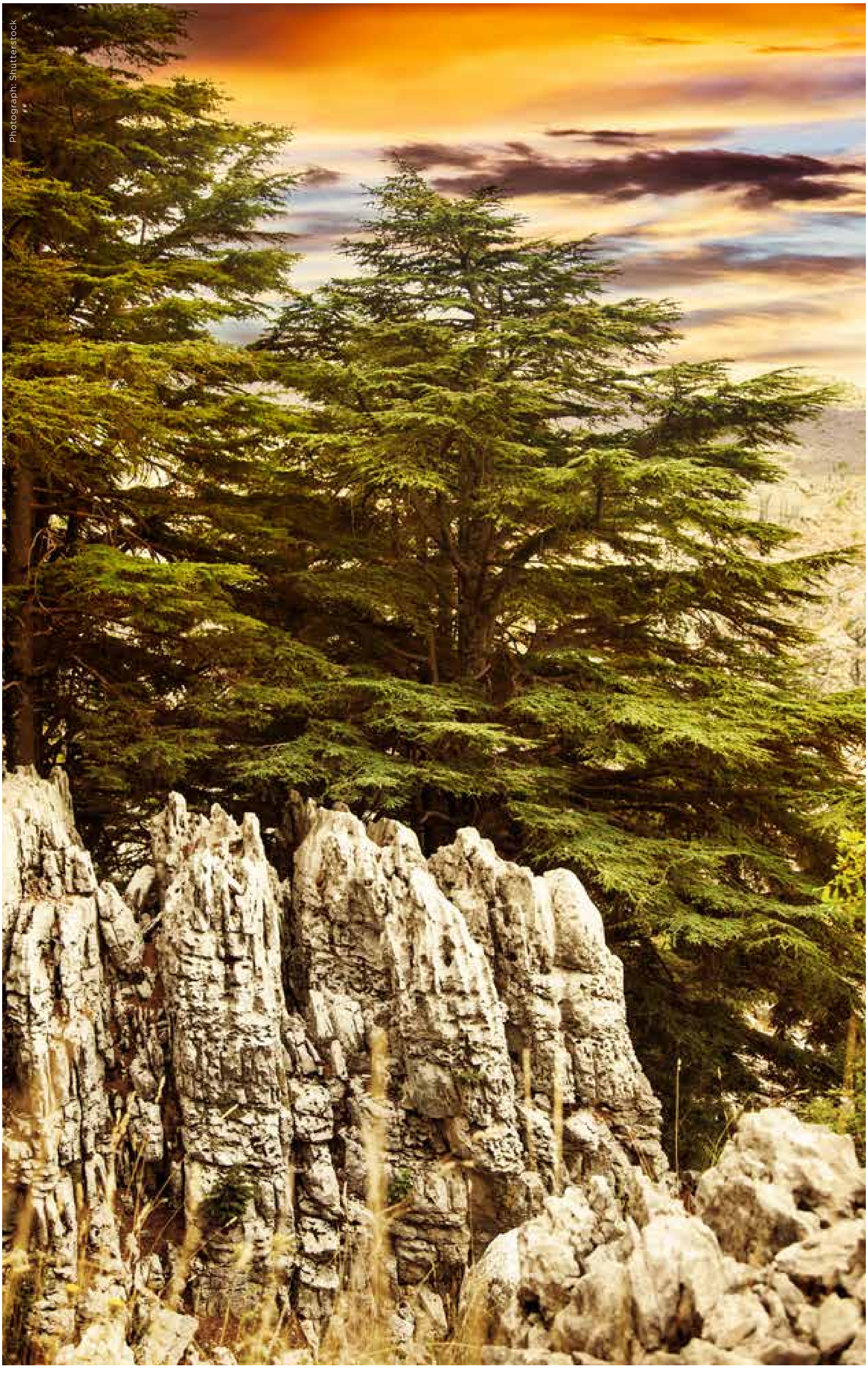
In 2017, the population of Lebanon was more than 6 million, according to the statistics of the World Bank (World Bank, 2019a). The population has grown by 24% since 2012, owing to the influx of refugees from neighbouring countries. Figure 1 illustrates the sharp increase in population since 2000.

Figure 1. Lebanon's population, 2000–2017



Source: World Bank, 2019a

The influx of refugees has swelled the population and added to power demand


Photograph: Shutterstock

Economics

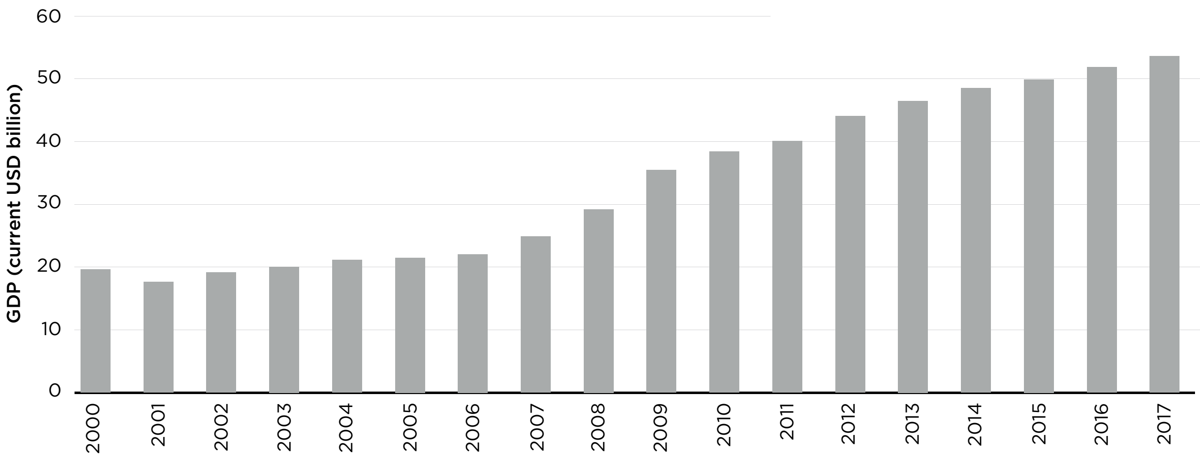
The Lebanese economy has traditionally relied heavily on the service sector – focusing on banking, tourism, construction and real estate – and activities are mainly undertaken by private companies. Lebanon's gross domestic product (GDP) was estimated at USD 53.6 billion (current USD) in 2017 (World Bank, 2019b).

Situated at the nexus of regional conflicts, Lebanon suffers from uncertainty over regional conditions and potential spill-overs. While achieving positive GDP results in recent years, the country still falls short of its economic potential.

Power generation costs also weigh heavily on the Lebanese economy. The national electricity company, Electricité du Liban (EDL), accounts for reported deficits of around USD 2 billion. The company faces global oil price fluctuations, while also being subject to government caps on oil purchases, with direct and indirect implications throughout the economy.

Challenges in the power sector echo throughout the economy

Figure 2. Lebanon's current GDP (billion USD), 2000–2017



Source: World Bank, 2019b

2. ENERGY SECTOR STATUS AND PLANS

Like other developing countries, Lebanon faces difficulties in compiling energy data and therefore is yet to generate a complete energy balance. The energy data employed by this study was largely based on two reports published by the Lebanese Centre for Energy Conservation (LCEC), namely the NREAP 2016–2020 (LCEC, 2016) and The First Energy Indicators Report of the Republic of Lebanon (LCEC, 2018).

1. Primary energy supply

Lebanon relies on imports to satisfy its energy demand. In terms of primary energy, consumption is met using the following six major components:

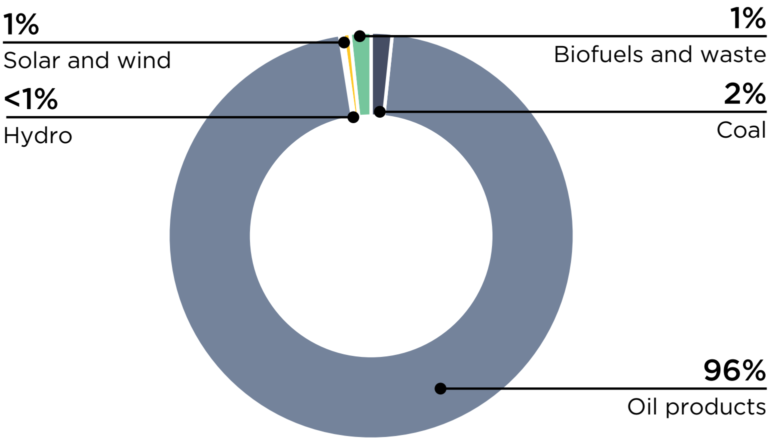
- liquid petroleum gas (LPG);
- gasoline;
- gas oil;
- kerosene;
- fuel oil; and
- bitumen.

The only sources of energy produced domestically include solar water heaters (SWHs), hydro power plants and a minor solar PV contribution.

In 2010, energy imports accounted for approximately 96.8% of primary supply, and only 3.2% was locally produced from hydroelectric power plants and SWHs. The share of primary energy imports did not change significantly between 2010 and 2015, as political instability in the region prevented uninterrupted imports of natural gas, thus forcing various plants to rely on fuel oil.

Primary energy production in Lebanon comes from mainly imported oil products. In 2016, fuel imports accounted for around 95% of overall energy production and imports. Some 96% of the country's total primary energy supply (TPES) in 2017 was sourced from primary and secondary oils, followed by coal at 2% (IEA, 2019).

Figure 3. Total primary energy supply by source (%)



Source: IEA, 2019

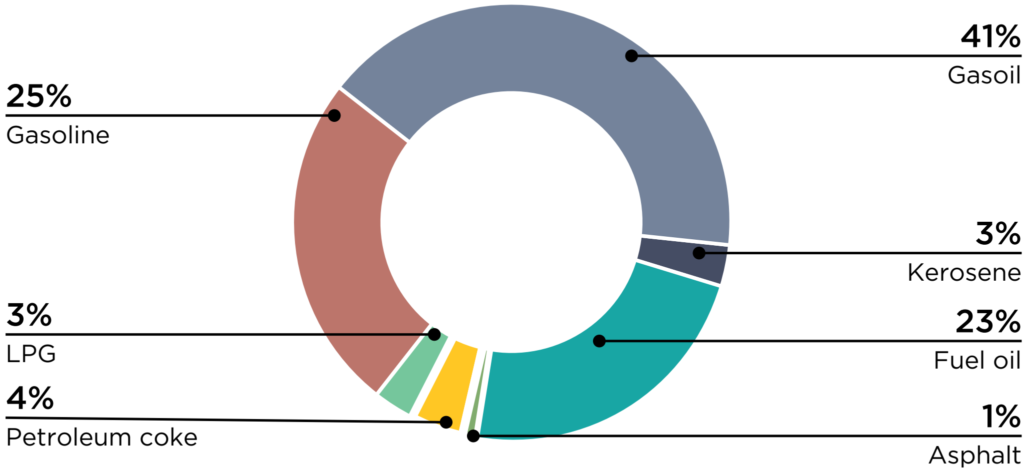
Figure 4 presents the fuel import mix for Lebanon in 2018 – calculated based on interviews with the MEW – with a total mix of 8 617 thousand tonnes of oil equivalent (ktoe).

This high dependence on imported oil products has increased the vulnerability of the Lebanese economy to oil price fluctuations. In addition, in recent years Lebanon has experienced significant intermittency of electricity imports owing to regional instability. As well as threatening the country's energy security, this has aggravated the electricity supply shortage. In this context, the country's high dependency on imports is a strong driver for the deployment of renewable energy sources, which will improve Lebanon's energy security.

As shown in Figure 8, the three dominant resources are gasoline, fuel oil and gas oil, which combined represent approximately 93% of total oil imports. Most of the gasoline is used in the transportation sector, while the fuel oil is predominantly consumed by EDL for electricity generation, with some consumed by large industries for private electricity generation.

Total final energy consumption (TFEC) in 2016 was largely met by imported oil and electricity, with the highest share being consumed in the transport sector (42%), followed by the residential sector (38%) and industry (15%).

Figure 4. Lebanese primary energy mix in 2018 (toe, %)



Source: LCEC, 2019a

***Fuel Import mix in toe**

Figure 5. TFEC by source

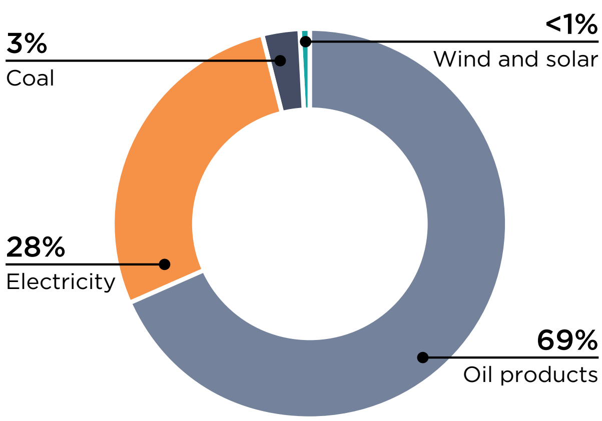
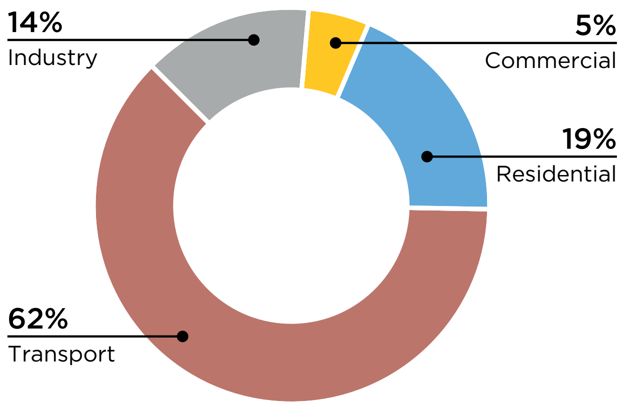


Figure 6. TFEC by sector



Source: IEA, 2019

For gas oil (diesel), there are four main areas of consumption: electricity generation by EDL, private generation, heating in houses, and use in the transportation sector – especially for large vehicles. However, defining the share of each of these four end-use categories represents a challenge, owing to analytical limitations.

Liquid gas represents a smaller share of the total mix, as it is most often consumed in small heaters or for cooking. Kerosene is more or less solely used in the transport sector to fuel aircraft, whereas asphalt is used in industries or road infrastructure. Figure 8 shows the evolution of imports of these products.

The evolution of imports is consistent with each of the oil products keeping the same share of total imports. In 2019, total imports reached 8 618 ktoe, representing a financial burden of around USD 6 248 million. Moreover, in 2019, an additional 350 ktoe of petroleum coke was imported, although this is not reflected in Figure 8 owing to incomplete information regarding its origin of and use.

Figure 7. Gas oil consumption streams in Lebanon

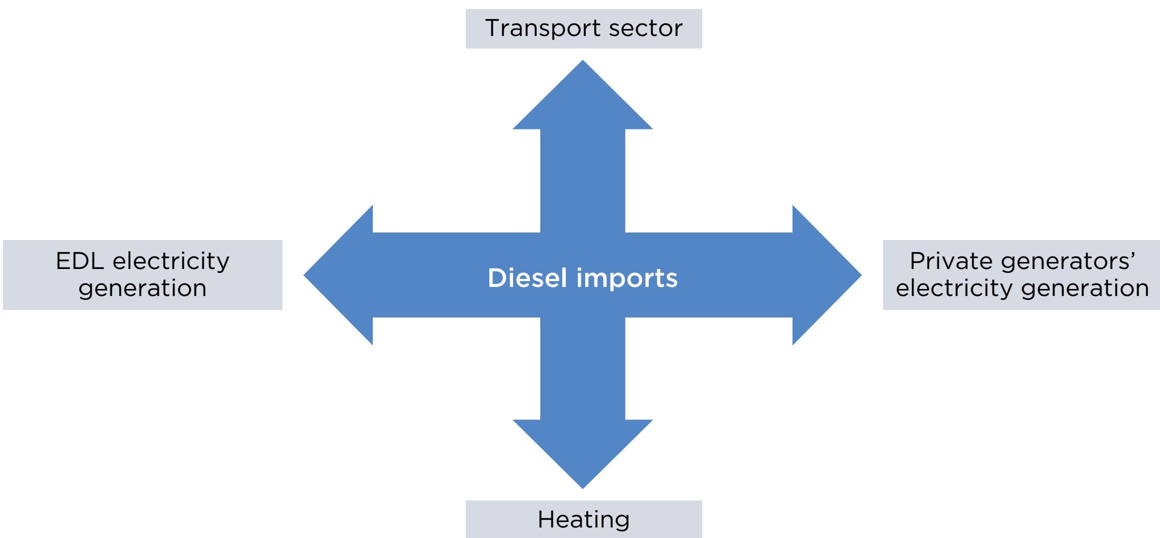
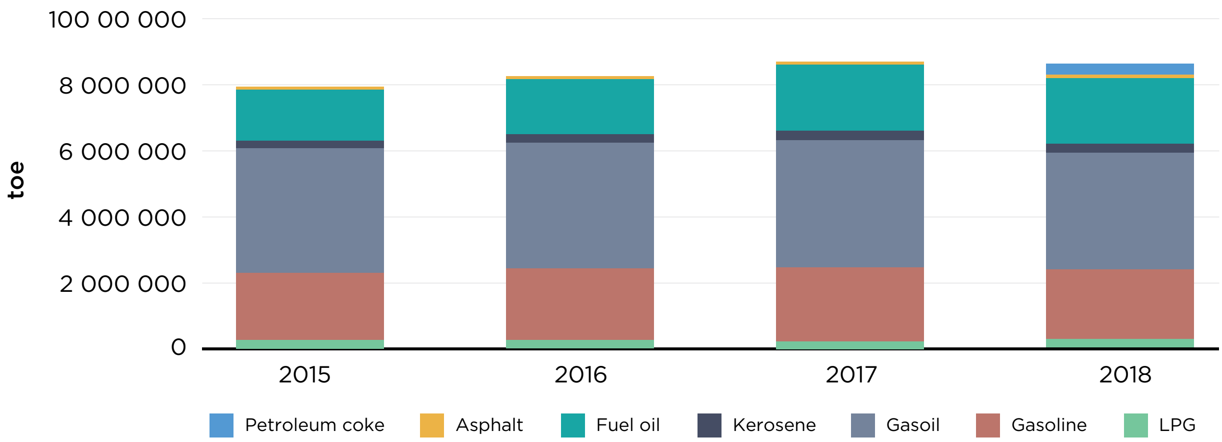


Figure 8. Oil imports 2015–2018



Source: MEW, 2019c

2. Energy sector governance

Institutional framework

The Ministry of Energy and Water (MEW) is the main stakeholder in the energy sector in Lebanon. It is essentially responsible for the country's electricity, water and oil portfolios, particularly at the strategic and planning levels in these areas.

The long-established Lebanese Centre for Energy Conservation (LCEC) has evolved to become the national energy agency. The LCEC is affiliated to the Lebanese Ministry of Energy and Water (MEW) and is the technical arm of the Ministry in all subjects related to energy efficiency, renewable energy and green buildings. The LCEC offers proven expertise and supports the Lebanese government in developing and implementing national strategies to save energy and reduce greenhouse gas emissions.

Electricite du Liban (EDL) is the vertically integrated company that manages the entire electricity sector in terms of generation, transmission and distribution. In 2010, the government introduced distribution service providers (DSPs) to open the door for private–public partnerships (PPP) in the distribution sector.

The scope of the DSPs covered network survey; asset management; customer service; construction of new feeders and substations; rehabilitation of existing feeders and substations; operation and maintenance of all assets in corresponding service zones; inspection and violation removal; meter reading and bill collection and advanced metering infrastructure (AMI). As of early 2019, there are three DSPs in operation.

Table 1. Sector governance

Institution	Function
Ministry of Energy and Water (MEW)	Directs the overall governance of the energy sector. Specific duties include, but are not limited to, proposing laws for the electricity sector and making electrical interconnection agreements with other countries.
Electricité Du Liban (EDL)	A public company that controls 90% of the electricity market. Has a monopoly on transmission and distribution for end-users.
Electricité Du De Zahlé (EDZ)	A private company previously owning the Zahle electricity concession – a two-year operation contract to continue providing Bekaa city and its surroundings with 24-hour electricity at a lower cost for consumers.
Electricity Regulatory Authority (ERA)	Sets conditions for the acquisition of licenses and permits for activities related to the production, transportation and distribution of power. Currently not established, mainly for political reasons.
Council of Ministers (CoM)	Reviews most decisions made by the MEW. Exercises the responsibilities of ERA until it is established.
Lebanese Centre for Energy Conservation (LCEC)	A subsidiary of MEW that works with the Ministry to set action plans and national strategies for energy efficiency and renewable energy deployment.
Central bank of Lebanon (BDL)	Initiated National Energy Efficiency and Renewable Energy Action (NEEREA) – a financing mechanism for green energy projects.
Litani River Authority	Establishes and maintains Lebanon's hydroelectric plant.

Legal framework

In 2002, Law 462 was presented with the objective of reforming the structure of the Lebanese energy sector. The law provided for the establishment of the Electricity Regulatory Authority (ERA) and allocated it the authority to grant electricity generation licenses to IPPs in order to feed the national grid.

Although Law 462 has been in force since 2002, it has never been implemented. Therefore, there is no regulatory body to issue licenses for new generation. Following an initial emphasis on privatisation in the period 1999–2002, the focus shifted towards public–private partnerships and corporatisation, leaving Law 462 somewhat outdated.

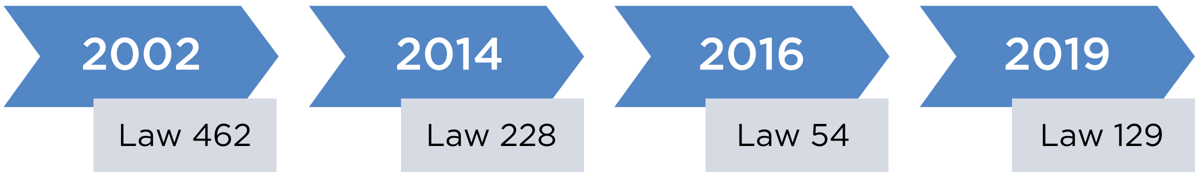
New laws have since been implemented to better reflect current conditions and stimulate the widespread adoption of renewable resources.

Law 288, adopted in 2014, further side-lined Law 462 by indicating that the Council of Ministers (CoM) – upon joint recommendations from the MEW and the Ministry of Finance (MoF) – could license IPPs. Law 288 was applicable for a period of two years (i.e., from April 2014 to April 2016), but was then extended in 2016 for another two years until 2018 under Law 54, despite the CoM not having issued any licenses.

In a recently published declaration, the Lebanese government said it would extend Law 288 to maintain current synergy, particularly within the renewable energy sector. As such, this law provided the opportunity to conclude a wind PPA contract, allowing for private sector entry to the Lebanese electricity generation market.

In 2019, the updated electricity policy paper adopted by the Lebanese government proposed to parliament an amendment of Law 288/2014 (under Law 129) to extend its application period for three additional years to allow the establishment of an independent electricity regulatory authority. This amendment is yet to be addressed by the Lebanese parliament.

Figure 9. summarises the legal evolution of the energy sector in Lebanon



3. Ongoing power sector reform

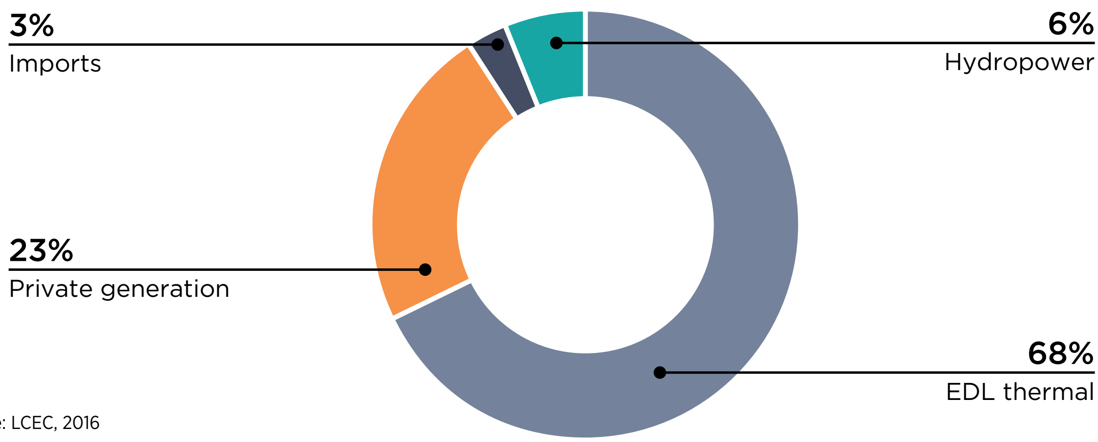
The Lebanese electricity sector has suffered since the mid-1990s, primarily due to a lack of investment that has led to the sharp deterioration of the sector's infrastructure. Hence, EDL has not been able to satisfy national electricity demand alone – a situation that has led to the development of smaller private diesel generators who operate in an unofficial capacity in a parallel electricity market.

The reduction in generation capacity has been amplified by poor maintenance and increased demand. Indeed, the recent influx of refugees to Lebanon has contributed to the increasing gap between electricity generation and demand, which reached 7 375 GWh in 2017 (MEW, 2019c).

The NREAP shows that for the year 2010, EDL thermal power plants generated approximately 68% of the total estimated electricity demand at around 15 934 GWh. Hydropower plants provided around 6% and electricity imports from Syria and Egypt provided 3%. The remaining 23% was supplied by decentralised private diesel generators distributed all over the country. The total electricity generated was slightly above 15 000 GWh, leaving around 900 GWh of electricity demand unserved.

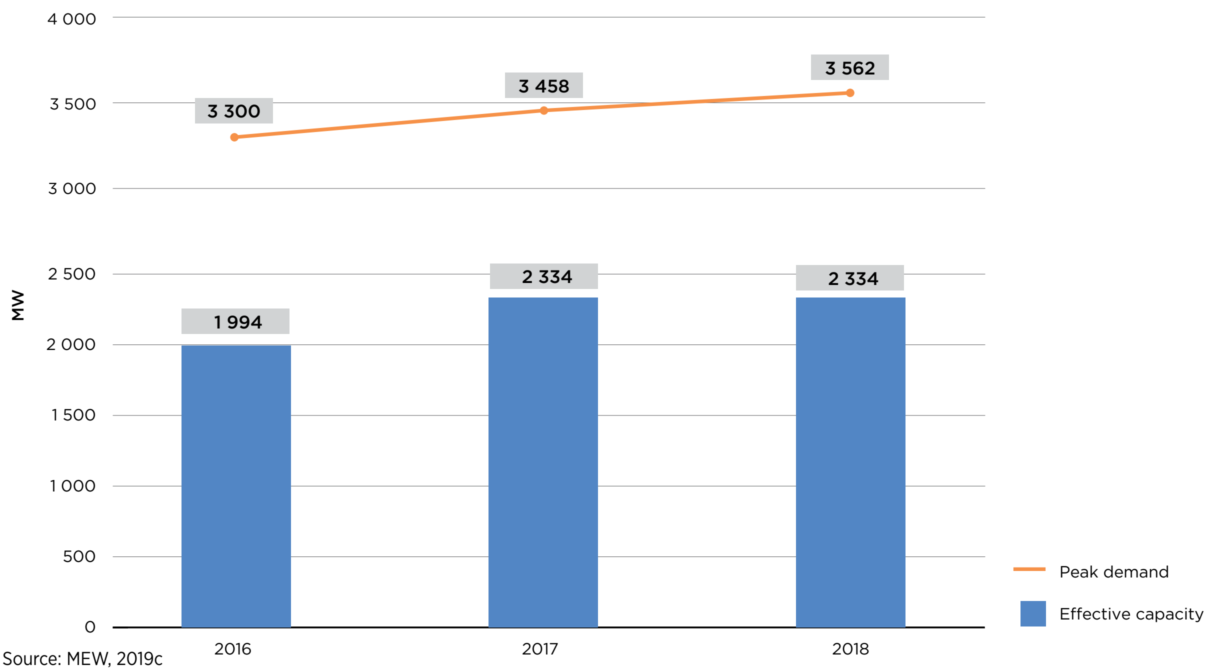
More recent data provided by the MEW highlights that the addition of several power plants in 2016–2017 increased overall generation capacity by approximately 700 MW, helping to close the gap between peak demand and installed capacity (MEW, 2019c).

Figure 10. Electricity generation mix in Lebanon, 2010



Source: LCEC, 2016

Figure 11. Installed capacity versus peak demand



Source: MEW, 2019c

Electricity demand was estimated in 2016 to be around 22 000 GWh (Electricité du Liban (EDL), 2018), marking an increase of 54.8% since 2010, when demand was estimated at 15 934 GWh (LCEC, 2010). However, annual electricity demand data adopted by the MEW vary between 3.8% and 5%; the difference is essentially caused by the demand calculation methodology employed by EDL and the demand consequences of the significant increase in population over a short period. For consistency with MEW data, the updated policy paper estimates a demand increase of 3% by 2020.

Table 2 shows existing EDL power plants along with their installed and effective capacities. The derating of most of these power plants is essentially a result of their age and maintenance needs.

COVID-19 pandemic recovery

Amid the coronavirus outbreak in early 2020, renewables and energy efficiency have become a key part of the country's recovery plans.

Table 2. Existing EDL power plant capacities and performance

Facility	Fuel type	Installed capacity (MW)	Effective capacity 2018 (MW)	Total generation cost (c$/kWh; USD 71/bbl)
Existing EDL				2018
Zouk 1 Thermal Power Plant	HFO	607	440	14.75
Jieh 1 Thermal Power Plant	HFO	343	180	19.39
Zouk 2 ICE Power Plant	HFO/NG-Z	198	157	10.83
Jieh 2 ICE Power Plant	HFO/NG-J	78	63	11.19
Zahrani I CCPP	DO/NG-ZAH	469	420	13.62
Deir Ammar I CCPP	DO/NG-DA	464	430	14.96
Baalbek Open Cycle GT	DO	64	57	20.26
Tyr Open Cycle GT	DO	72	56	21.44
Richmaya-Safa Hydro	-	13	3	3.66
Naameh (Landfill Gas)	-	7	7	1.00
Existing barges				
Power Barge Zouk	HFO/NG-Z	187	195	13.95
Power Barge Jiyeh	HFO/NG-J	187	195	14.03
Existing IPPs				
Litani Hydro	-	199	47	3.97
Nahr Ibrahim Hydro	-	32	17	2.65
Bared Hydro	-	17	6	2.65
Kadisha Hydro	-	21	15	2.65
Hrayche Thermal Power Plant	HFO	35	46	20.13
Power imports				
Imports from Syria and Egypt		276	69	15.35

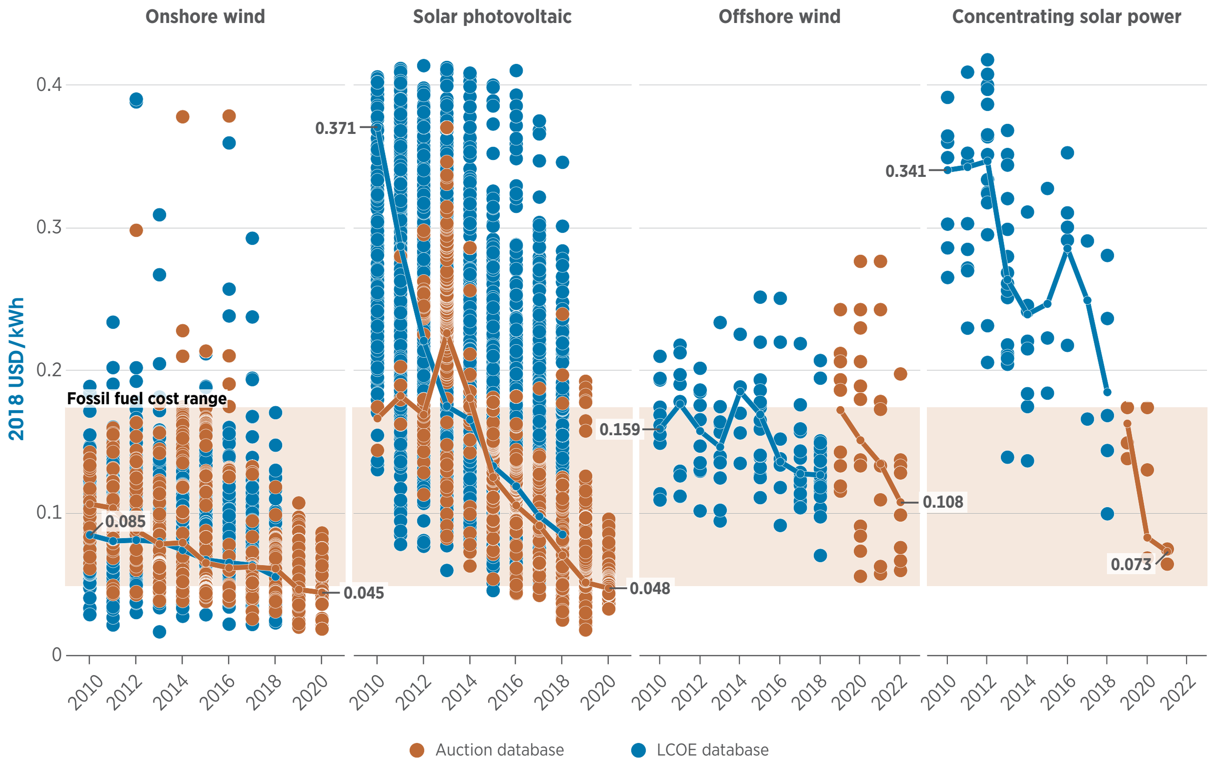
Source: MEW, 2019b

In addition, Table 2 shows the corresponding generation cost of each of these power plants. The new power plant at Zouk have the lowest cost of 10.83 US cents per kWh, whereas in the case of the Hrayche, Tyr and Baalbek power plants, the cost is more than 20 US cents per kWh. This highlights the additional benefits of deploying renewable energy in Lebanon, along with the cost-competitiveness of renewables compared to fossil-fuel based sources.

IRENA's Renewable power generation costs in 2018 finds that the continued decline in costs for solar PV and onshore wind – as well as CSP and offshore wind – will lead to renewable power becoming more competitive than even the cheapest new source of fossil fuel-fired electricity by 2020.

Figure 12 shows that for IRENA's auction data for utility-scale solar PV, suggests that the average price of electricity could fall to USD 0.048/kWh in 2020, a reduction of 44% compared to the global weighted average LCOE of projects commisioned in 2018. This decline is further amplified by the decrease in the cost of dispatchable CSP and battery storage technologies, improvements in grid operation and an emerging suite of electricification technologes in end-uses (from electric vehicles to heat pumps).

Figure 12: Global weighted average total installed costs and project percentile ranges for CSP, solar PV, onshore and offshore wind, 2010–2018



As of 2010, the developing renewable energy sector has been supported by a clearer national action plan, driven by the electricity reform paper (Bassil, 2010) and the first National Energy Efficiency Action Plan (NEEAP), (LCEC, 2010), prepared by the MEW and the LCEC, respectively, and adopted by the Lebanese government. On 8 April 8, 2019, the then Lebanese government adopted the update to the electricity reform paper prepared by the MEW in collaboration with the World Bank. This plan relied on the 2010 action plan but introduced changes to some of the approaches adopted in previous versions.

The plan began by addressing the causes of the electricity problem in Lebanon that were summarised as follows:

- *Tariffs:* tariffs have been fixed in Lebanon since 1994 at an average of USD 0.092 per kWh, corresponding to an oil price of USD 20 per barrel, while not taking into consideration fluctuating oil prices, which rose to more than USD 140 per barrel in 2008 and significantly increased EDL's financial deficit.

- *High operation costs:* Power plants in Lebanon rely mainly on heavy fuel oil and diesel oil, thus increasing their generation cost in comparison to natural gas. Moreover, the newest power plants in Deir Ammar and Zahrani were originally meant to be operated using natural gas, but are currently using diesel, increasing their generation cost and leading to negative environmental impacts.

- *Old power plants with low efficiency:* These require significant maintenance, decreasing their operational availability.

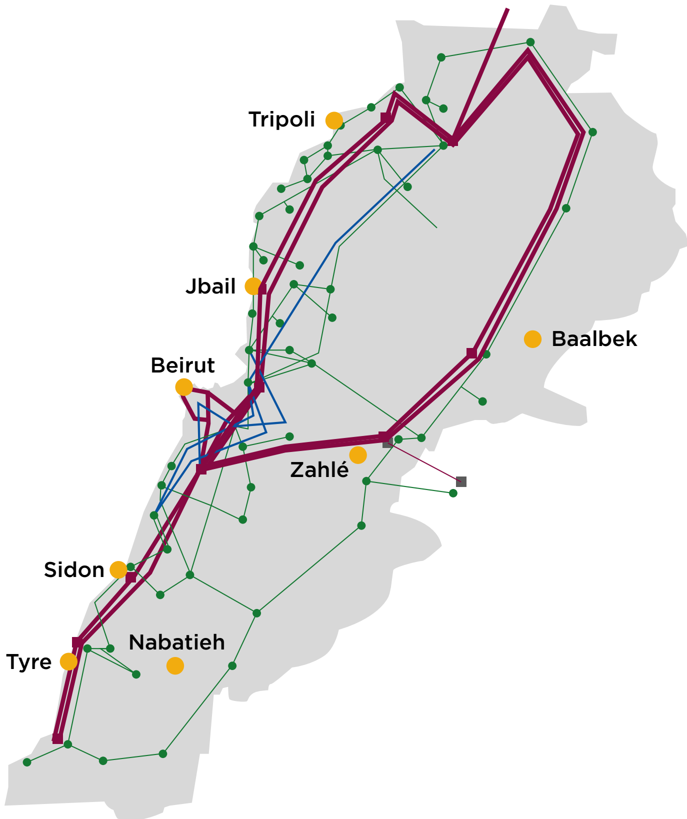
- *High technical losses:* Both transmission and distribution grids face losses equivalent to 16.5% despite recent efforts by the Ministry, EDL and the distribution service providers (DSP) to rehabilitate the underdeveloped grid, as shown in Figure 13.

- *High non-technical losses:* These have reached 21%, largely owing to violations and illegal connections to the distribution grid that EDL is seemingly incapable of addressing.

- *Uncollected bills: This are* estimated at around 5%, and sometimes as high as 30% due to strikes by EDL and DSPs employees, in addition to uncollected electricity revenues from public institutions and refugee camps estimated at USD 1.820 billion and USD 444 million, respectively.

- *Impacts of regional crises:* The Lebanese Crisis Response Plan (LCRP) 2017–2020 estimated that the refugee crisis has cut electricity availability by 500 MW – equivalent to approximately five hours of electricity per day – obliging the state to rely more on private generators, costing around USD 150 million USD (UNDP, 2016).

Figure 13: EDL transmission network



Source: Based on EDL, 2019
Disclaimer: boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.


Photograph: Shutterstock

To remedy these factors, in the updated electricity reform paper the Ministry proposed the following potential solutions:

Decreasing technical and non-technical losses and increasing EDL financial income

To achieve a decrease in technical losses, the MEW proposed a series of practical actions beginning with the implementation of the transmission sector master plan adopted by the Lebanese government in 2017. It proposed that this be complemented by a series of projects to alleviate transmission bottlenecks in several locations. In the distribution sector, DSPs have committed to reduce distribution technical losses through grid rehabilitation. Combined, the proposed actions will potentially reduce technical losses from around 16.5% in 2018 to less than 8% in 2022.

A campaign was also launched by MEW to remove illegal connections, thereby lowering non-technical losses from 21% in 2018 to around 3% in 2021.

In 2019, EDL began installing smart electricity meters as part of its advanced metering infrastructure project to add more than one million meters across Lebanon by 2022. These meters will allow EDL to introduce modern electricity services while monitoring and lowering non-technical losses.

Combining both actions related to grid losses would allow EDL to lower total losses from around 34% in 2018 to less than 11% in 2022, enabling a saving of around USD 640 million during the period 2018–2021.

Moreover, addressing the losses will increase EDL cash flow by more than USD 2 billion over this period through the following actions:

- Collection of existing **uncollected bills**: USD 182 million;
- Updating the **collection process** of EDL bills: USD 370 million;
- Collection of electricity bills from **refugee camps**: USD 296 million;
- Collection of outstanding bills from **public institutions**: USD 1.213 billion;

Increasing generation capacity, improving efficiency and reducing costs by switching to natural gas

The plan proposed to increase the generation capacity of EDL by combining both short term temporary solutions with long term permanent solutions – installing 1 450 MW of temporary generation combined with around 3 100 MW of permanent generation.

This increase in generation capacity will allow EDL to close the gap between electricity supply and demand, thereby reducing dependency on private generators by 2020, reducing the electricity bill for consumers and supporting the Lebanese economy by providing a reliable, low-cost electricity supply.

Decreasing EDL's generation costs will alleviate its financial deficit and generate national economic benefits by adding new higher efficiency power plants and removing old, expensive and inefficient ones with high maintenance costs.

Moreover, to further lower generation costs and environmental impacts, the MEW plans to introduce natural gas starting in mid-2021 in most of its power plants by installing floating storage and regasification units. Meanwhile, the MEW will allow IPPs to procure their own fuel during the transition phase, which may introduce natural gas to the power generation sector even earlier.

Increasing tariffs

In Lebanon, consumers are issued with two electricity bills with separate tariffs: one for EDL and the other for the private generators that complement EDL's supply. Private diesel generators issue bills in accordance with a tariff issued by the MEW, which is updated on a monthly basis. EDL generation costs were estimated in 2018 at USD 0.14 per kWh, which is far higher than the average cost estimated at 0.092 per kWh. The tariff from private diesel generators is USD 0.264 per kWh. The MEW has been working with the World Bank to propose a new pricing structure that will include an increase in tariffs based on the expected increase in consumption.

3. RENEWABLE ENERGY STATUS, TARGETS AND POLICIES

1. Overview

Renewable energy sources have largely been limited to biomass heating in rural areas and hydroelectric power plants installed before the 1970s that represented more than 75% of the electricity produced in Lebanon at that time.

As per Table 3, total installed hydroelectric capacity is 286 MW; however, several plants lack proper maintenance, which has led to reduced efficiency and production losses of around 30–40%. Most of these power plants belong to the water concessions in Lebanon, where the currently adopted tariff of USD 0.1 per kWh, does not constitute sufficient motive for these institutions to properly maintain the plants.

Today, most of the newly added renewable energy installations are in the power sector – mostly decentralised solar rooftop PV, which is estimated to have increased from 330 kWp in 2010 to 56.37 MWp in 2018, generating around 83.5 GWh in the same year (LCEC, 2019c). While all end-use sectors are important to address, the focus is on the power sector due to the widening electricity deficit, coupled with the need for greater energy security.

Table 3. Existing hydroelectric power stations in Lebanon

River	Establishment	Plant(s)	Year of installation	No. of units	Installed capacity (MW)
Litani/Awali rivers	Litani Water Authority	Markaba, Awali, Joun	1961, 1964, 1967	7	199
Nahr Ibrahim river	Société Phénicienne des Forces de Nahr Ibrahim des Eaux et Electricité	Chouane, Yahchouch, Fitri	1961, 1955, 1951	8	32
Kadisha valley	La Kadisha, Société Anonyme d'Electricité du Liban Nord	Bechare, Mar Licha, Blaouza II, Abu-Ali	1924, 1957, 1961, 1932	11	25
Nahr Al Bared	Al Bared Concession	Al Bared 1, Al Bared 2	1936	5	17
Safa spring	Electricité du Liban	Richmaya–Safa	1931	3	13
Total installed capacity					286

Source: MEW, 2018.

2. Renewable energy targets and policy framework

Targets

In 2018, the Prime Minister announced a renewable target of 30% of electricity consumed by 2030, as reflected in the latest electricity reform paper adopted by the Lebanese government in 2019.

Prior to 2018, the government had set a renewable energy target of 12% of total primary energy consumed (electricity and heating) by 2020. In this regard, in 2015, the MEW and LCEC decided to dedicate a separate document to presenting the proposed goals and actions to meet these ambitious targets – the National Renewable Energy Action Plan (NREAP) (LCEC, 2016). Moreover, Lebanon ratified the Paris Agreement in Parliament under law 115 in March 2019; so, despite these circumstances, renewable energy commitments were made as part of its Nationally Determined Contribution (NDCs) to the Paris Agreement.

Lebanon's NDC includes both unconditional and conditional renewable energy targets. Unconditional targets include meeting 15% of power and heating demand using renewable energy sources by 2030, while conditional targets include satisfying an additional 5% of power and heating requirements from renewable energysources. Thus, the current NDC aims for a total share of 20% by 2030.

The national action plan on renewable energy

The foundations of renewable energy planning were introduced in the 2010 electricity reform paper (Bassil, 2010) and expanded in the first National Energy Efficiency Action Plan (NEEAP) for Lebanon (LCEC, 2010) that combined both renewable energy and energy efficiency initiatives. In 2015, separate action plans were adopted for renewables and energy efficiency covering the period 2016–2020.

The first NEEAP for Lebanon introduced fourteen initiatives in 2010 related to renewable energy and energy efficiency, combined. The most successful was initiative 11, which introduced the National Energy Efficiency and Renewable Energy Action (NEEREA) dedicated to distributed solar applications.

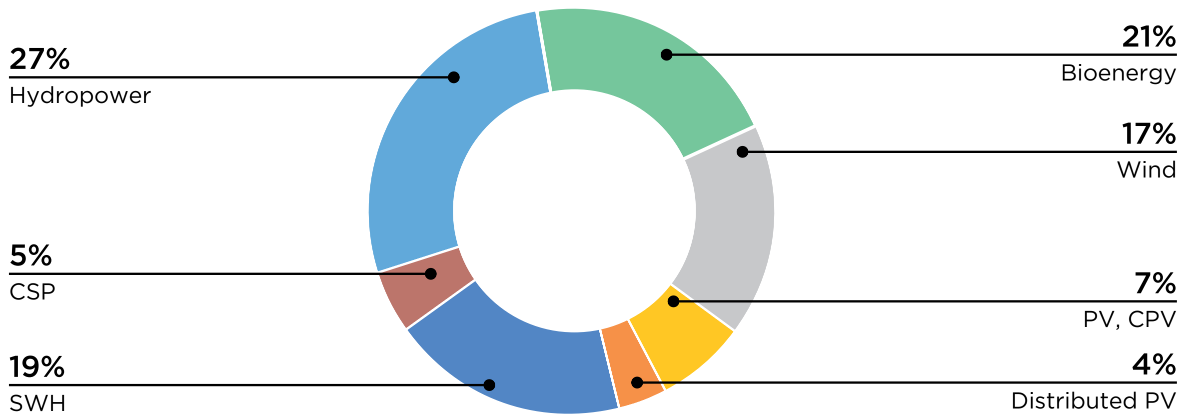
The NEEAP 2010–2015 (and then 2016–2020) has been in effect since 2011 and has acted as the governing framework for the deployment of renewable energy in Lebanon. The NREAP 2016–2020 placed emphasis on certain renewable technologies over others. The following sections highlight the current resource availability and development potential for various renewable energy sources in Lebanon, along with the corresponding projects in the pipeline for 2030.

The NREAP 2016–2020 was presented in November 2016 by the MEW through the LCEC. It outlines a strategic plan for the renewable energy sector that aims to achieve the set renewables target of 12% of consumed primary energy for both electricity generation and heating purposes by 2020.

The NREAP relied on a 2010 baseline to estimate the primary energy consumed for electricity generation and heating at around 6 069 ktoe. Based on this figure, consumption in 2020 was estimated at 6 389 ktoe, which meant that the target was to produce the equivalent of 767 ktoe from renewable sources by 2020.

To achieve this, the methodology adopted focused on estimating the available potential of relatively mature renewable energy sources by building three different scenarios: optimistic, realistic and pessimistic. Based on a partial substitution methodology, the renewable energy mix was optimised to achieve the target mix presented in Figure 14, leading to the targeted installed capacities illustrated in Figure 15.

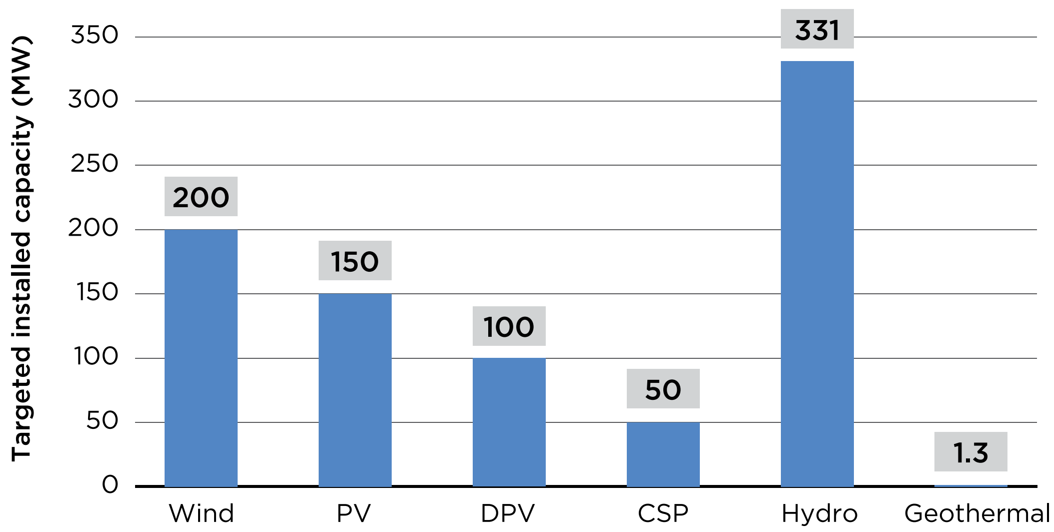
Figure 14: Renewable energy target resource mix in the NREAP 2016–2020



***CPV: Concentrator photovoltaics.**

Source: LCEC, 2016

Figure 15: Renewable energy targeted installed capacities in the NREAP 2016–2020

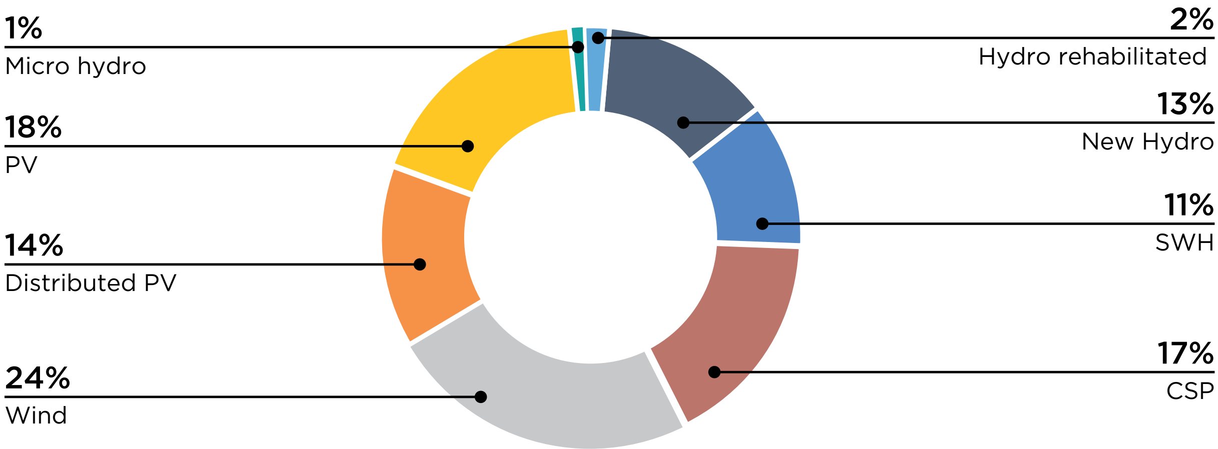


Source: LCEC, 2016

The NREAP also targeted SWH installations of around 1 054 000 m^2 and the equivalent of 166.6 ktoe generated from biomass energy. The investment required for the full implementation of the NREAP was estimated at USD 1.737 billion, with the corresponding shares of investment presented in Figure 16.

The national action plan for renewables calls for investments of USD 1.7 billion

Figure 16: Shares of total investment per technology in the NREAP 2016–2020



Source: LCEC, 2016

3. Renewable energy potential, status and driving policy instruments

Hydropower

Hydropower was the first form of renewable energy to be deployed in Lebanon and plays a major role in supplying renewable electricity to the country. However, low contracted prices and lack of maintenance and/or refurbishment of hydropower plants have led to a continuous drop in the share of hydropower in the energy mix.

The main potential of hydropower in Lebanon is derived from four main sources: rehabilitation of existing power plants; construction of new power plants; micro-hydro run-of-river applications; and generation from non-river sources. The NREAP 2016–2020 finds that rehabilitation of existing power plants can help increase their annual generation by more than 1 000 GWh. With the construction of new power plants, the available potential is estimated at around 368 MW in the peak scheme and 263 MW in the run-of-river scheme (Sogreah-Artelia, 2012). The last source of hydropower potential derives from micro-hydro and non-river sources estimated to be around 5 MW (CEDRO, 2013).

The announced targets within the NREAP, as shown in Table 4, are 331.5 and 473 MW in 2020 and 2030, respectively, including existing power plants to be rehabilitated.

Table 4: Hydroelectric targets and potential

	2020 target	2030 target	Contracted capacity	Project in the pipeline	Potential
Hydroelectricity	331.5 MW	473 MW	N.A.	300 MW	Additional 382–487 MW

In March 2018, the MEW launched an expression of interest (EOI) for the installation of hydroelectric power plants on various Lebanese rivers. The MEW received 25 EOIs from 59 companies from 15 different countries to install more than 300 MW.

The main challenge lies in the fact that most of the existing concessions, except for the Litani River Authority concessions, are used exclusively for agricultural and irrigation purposes rather than hydropower generation. To promote hydropower in these concessions, the Lebanese government delegated the MEW to negotiate concessions as per the newly adopted electricity plan in 2019 to find an appropriate solution for the current situation.

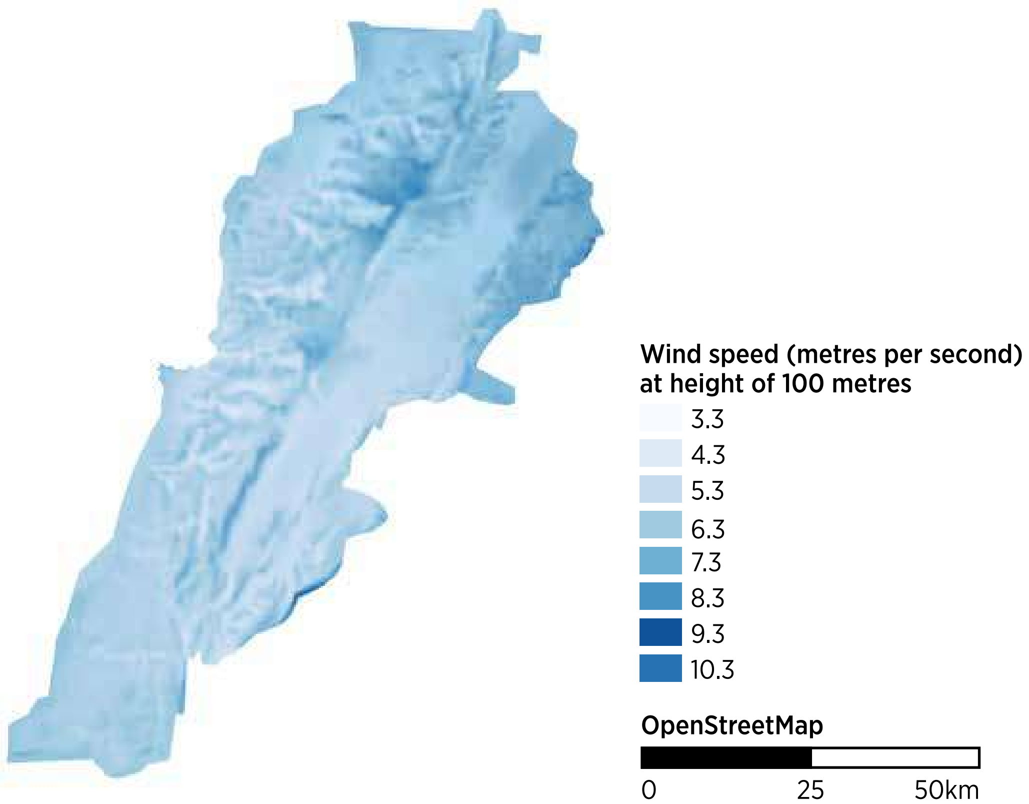
Onshore wind

The initial evaluation of wind potential in Lebanon began in 2011 with the publication of the wind atlas (Garrad Hassan, 2011) that estimated a mean wind capacity potential of 6 100 MW. According to the LCEC, while considering assumptions on installation density, minimum wind speed requirement and maximum slope constraints, this potential must be decreased to 5 400 MW with a generation capacity of 12 139 GWh, resulting in available potential of 1 500 MW.

IRENA's assessment conducted exclusively for this report in 2019 presents a slightly higher potential of 6 233 MW. The assessment is based on the Agency's suitability mapping approach, which scores each 1 km2 parcel of land on resource quality, proximity to transmission lines, topography, population density, protected areas and land cover. Results from this assessment conducted at 100 m height indicate that over 1 558 km2 of land in Lebanon is suitable for utility scale wind farms. This translates to around 6 233 MW of wind capacity.

The NREAP has set wind targets at 200 MW and 450 MW in 2020 and 2030, respectively, with approximate investment needs of USD 490 million in 2020. Table 5 outlines the targets for 2020 and 2030, along with contracted capacity and projects in the pipeline as of 2019.

Figure 17: Wind resource potential (wind speeds at 100 m height, m/s)



Source: IRENA (n.d.), Global Atlas for Renewable Energy, DTU Global Wind Dataset v1 ;1 km onshore wind speed at 100 metres height.

Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

Table 5: Wind power potential and targets; contracted and planned projects as of 2019

	2020 target	2030 target*	Contracted capacity	Project in the pipeline	Potential
Wind	200 MW	450 MW	200-220 MW	500 MW	Additional 382–487 1 500 MW

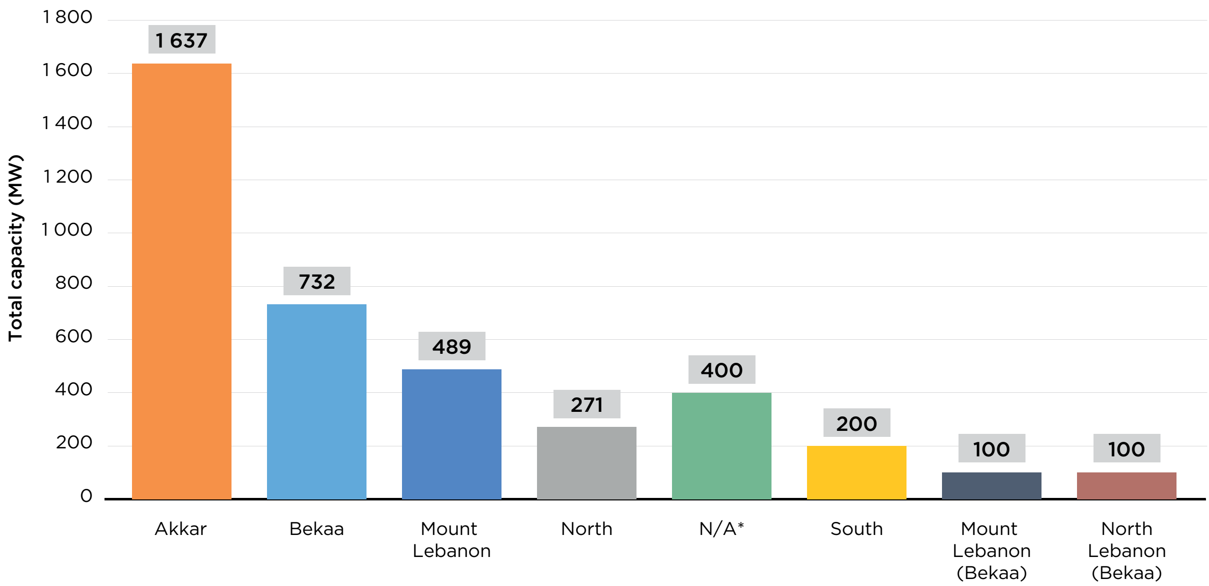
*Before Remap 2030 Scenario

The main policy instrument driving wind deployment is competitive procurement, or auctions. The first round was launched in 2013 when developers were invited to bid for the licenses to develop three wind farms in the under-developed region of Akkar, totalling a capacity of between 200 and 220 MW, depending on the wind turbines employed.

The contracted price, after several rounds of negotiations, dropped from more than USD 0.14 per kWh to USD 0.1045 per kWh for the first three years and USD 0.096 per kWh for the remaining seventeen years of the contract. This price included land leasing, obtaining licenses, financing and insurance costs, and the cost of the transformation stations,and the cost of the transformation stations, with any required grid reinforcement to be considered as client assets.[1]

The second round of auctions was launched through an expression of interest (EOI) in April 2018, receiving 42 offers from 74 companies representing 21 countries with an estimated capacity around 4 000 MW, while the required capacity was between 200 and 400 MW. The Request for Proposals (RfPs) for the project were released to companies that submitted their interest during the International Beirut Energy Forum held in Beirut in September 2018. Figure 18 shows the total capacity received in each region of Lebanon, according to the Wind Atlas (GH, 2011), with the highest concentration being in the Akkar region.

Figure 18: Total capacity per region in response to the second EOI/round of wind auctions



Based on IRENA's work on auctions, a number of factors relevant to auction design have been identified – including country-specific conditions – that influence the price resulting from auctions, as summarised in Box 2.

*** N/A: No specific land attributed.**

Source: LCEC, 2019b.

1 Assets to be transferred to the client (EDL) as per the PPA contract.

Box 1 Factors influencing the price resulting from auctions and key considerations in auction design

As noted in IRENA's *Renewable energy auctions: Analysing 2016,* many factors shape the prices that emerge from auctions, but they may be grouped into four categories (Figure 20):

1) country-specific conditions such as resource availability and the costs of finance, land and labour;

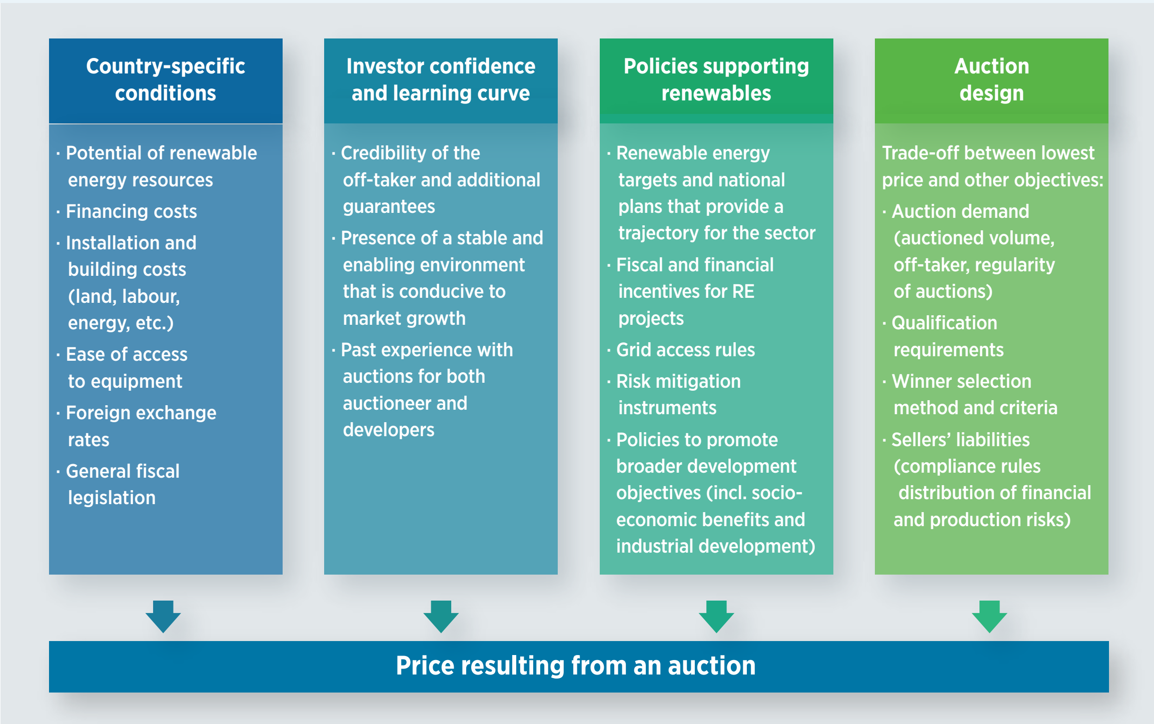
2) the degree of **investor confidence** (availability of clear targets, credible off-taker);

3) other policies related to renewable energy (grid policies, priority dispatch, local content rules); and

4) the **design of the auctio**n itself, taking into consideration the trade-offs between obtaining the lowest price and achieving other objectives.

Country-specific conditions, investor confidence, auction design and policy factors all influence final electricity prices

Figure 19: Factors affecting auction prices



Source: IRENA (2017a), *Renewable energy auctions: Analysing 2016.*

For further information on auction design, see Annex 1.

Solar power

Lebanon had a cumulative installed solar PV capacity of just 56.37 MW at the end of 2018 (LCEC 2019d), including large-scale projects and distributed installations. IRENA's Global Atlas for Renewable Energy (see Figure 20) indicates that annual average solar irradiation in Lebanon ranges between 1 520 kWh/m2/year and 2 148 kWh/m2/year, with a significant majority of areas being above 1 900 kWh/m2/year.

Building on this solar irradiation data, IRENA estimates that the potential for utility scale solar PV could reach 182 GW. The estimate is based on the Agency's suitability mapping approach, which scores each 1 km2 parcel of land on resource quality, proximity to transmission lines, topography, population density, protected areas and land cover. The results of this assessment, conducted specifically for this report, indicate that over 5 558 km2 of land in Lebanon is suitable for utility scale solar PV, having scored above 65%.

Based on a PV land-use footprint of 33 MW/km2, this translates to around 182 615 MW of solar PV capacity. This estimate was found to be more than twice that of prior assessments by NREAP, at 87 000 MW.

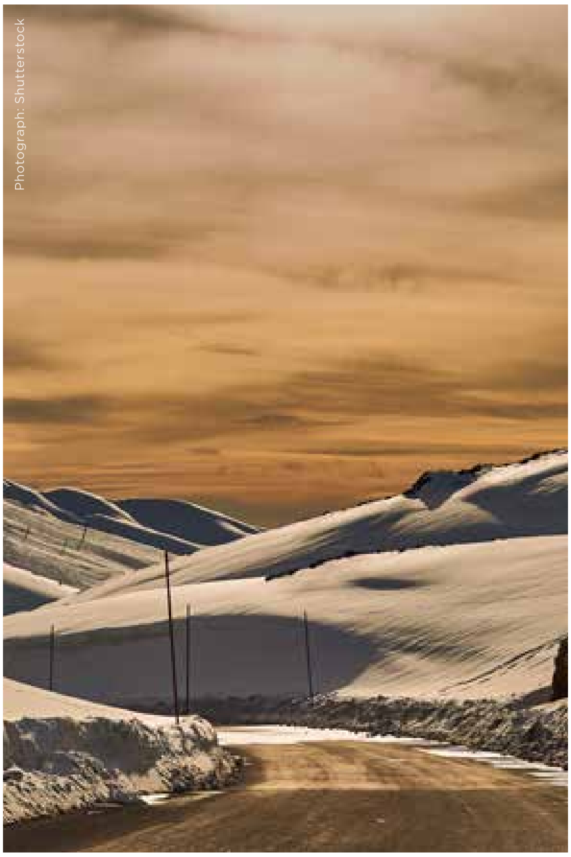
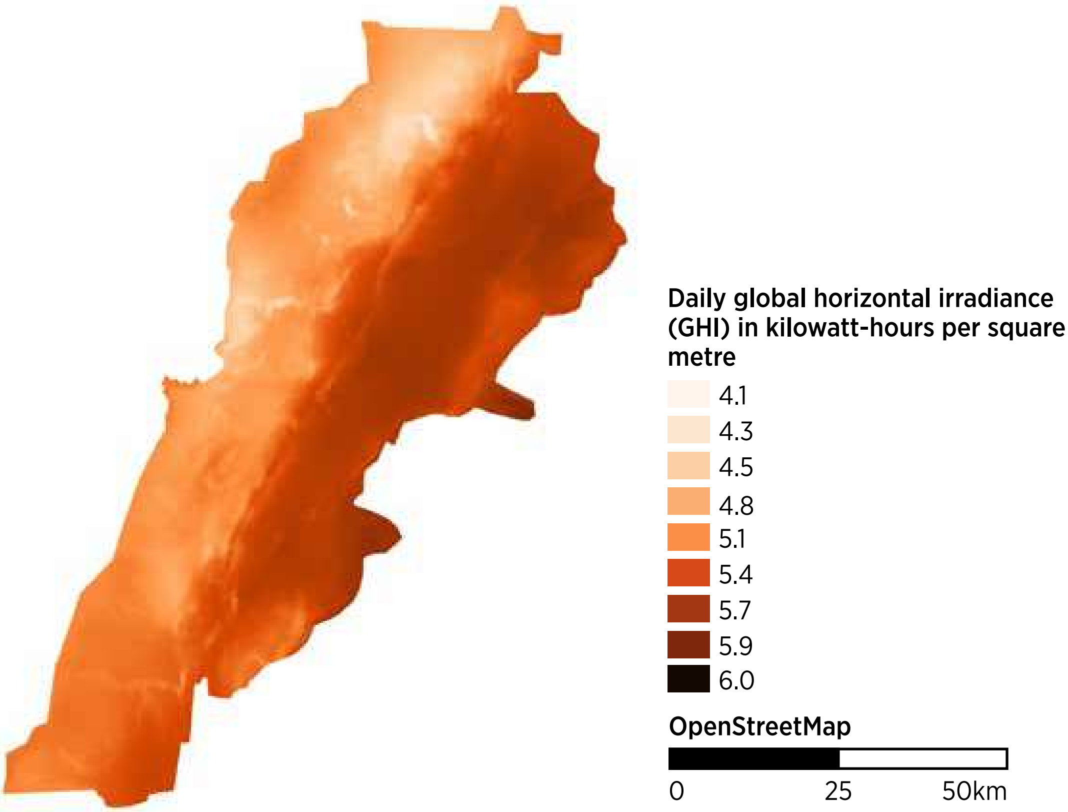


Figure 20: Solar resource potential: Annual average daily GHI (kWh/m²)



Source: IRENA (n.d.), Global Atlas for Renewable Energy; World Bank; 1 km Global Horizontal Irradiation.

Disclaimer: Boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA.

i. Grid-connected large-scale solar PV

The threshold for large scale solar PV adopted in the NREAP is 1 MWp. Therefore, the targets in the following sections relating to centralised installations have a capacity equal to, or more than, this threshold.

The significant solar PV resource potential shows that the limitations to this technology largely comprise economic, grid infrastructure and management, land, social and environmental constraints. According to the NREAP, the national solar PV targets are 150 MWp and 300 MWp in 2020 and 2030, respectively.

The deployment of large-scale solar PV projects is driven by competitive procurement either via the engineering, procurement and construction (EPC) model – whereby a private company installs the project and hands it over to EDL for operation – or the power purchase agreement (PPA) model, whereby private developers are invited to bid for a 20-year contract to sell power to EDL.

The first project installed in Lebanon was the Beirut River Solar Snake (BRSS), initiated by the MEW in 2013 with the aim of installing a PV farm of more than 1 MWp on the bed of the Beirut river. The demonstration project of 1.08 MWp was highly significant, having proved the feasibility of large-scale solar PV in Lebanon and thereby contributed to de-risking the sector.

The BRSS project was developed following an EPC model and transferred to EDL in 2016 through the signature of an operation and maintenance services contract for two successive years. EDL launched a bid at the end of 2018 to install the second phase of the BRSS project, with a capacity of more than 7 MWp. The results of the bid are expected by December 2019, and the project to be commissioned in the first half of 2020. Following the BRSS, the second project within the 1 MWp capacity formed part of the first phase of the Zahrani Oil Installations, under the umbrella of a broader 3 MWp target that aims to satisfy the full energy needs of the installations.

In early 2017, Lebanon adopted the first auction for solar PV. The MEW launched an expression of interest to install 12 PV farms, each with a capacity of 10 to 15 MW, in the four main regions of Lebanon. In response to the bid, LCEC and the MEW received 265 expressions of interest resulting in a total capacity of more than 3 500 MWp, while the bids aimed at capacities ranging between 120 to 180 MW. Another request for proposals was launched in May 2017; it elicited 42 offers by the end of October of 2017, presented by 138 companies from 26 different countries. The first evaluation phase concluded in early 2019 qualified 28 companies to the final phase before financial evaluation, with the lowest bid price received at 5.7 US cents/Kwh (MEW, 2019a).

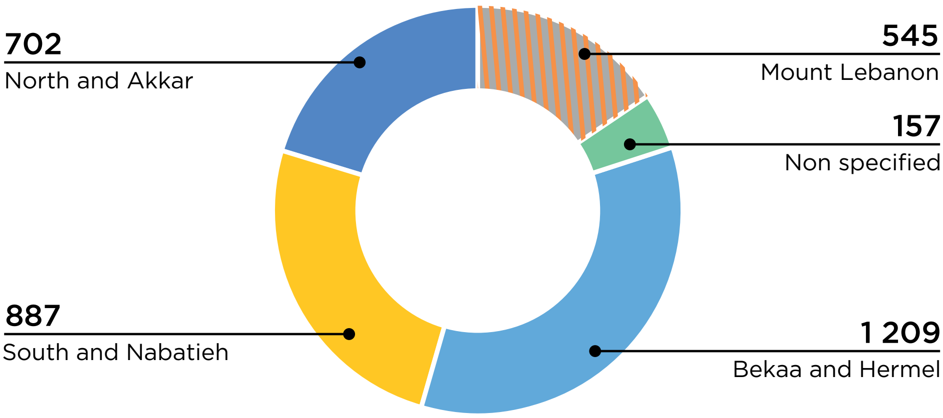
The highest concentration of projects and capacities were in the Bekaa and Hermel regions due to their higher irradiances (approximately 20% or more) and lower land prices (see Figure 21).

Table 6: PV targets and potential

	2020 target	**2030 target***	**Contracted capacity**	**Project in the pipeline**	**Potential**
Large-scale PV	150 MWp	300 MWp	2 MWp	1 030 MWp	87 636 MWp

*Before Remap 2030 Scenario

Figure 21: Total capacity per region in response to the EOI of the first round of PV projects

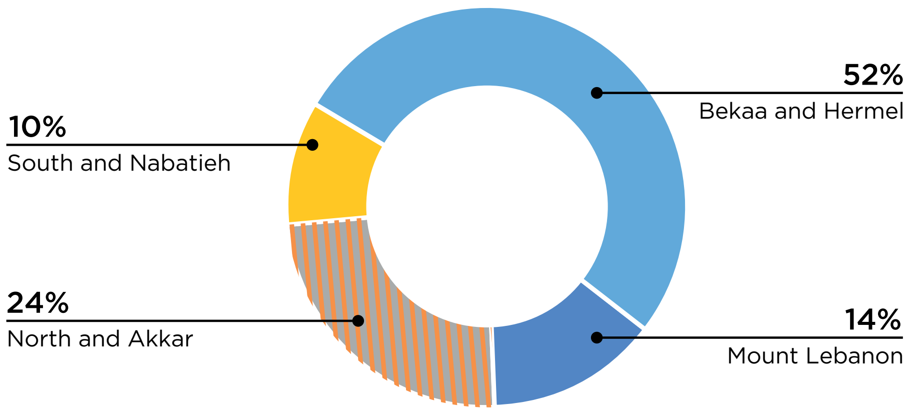


Source: LCEC, 2019b

In 2018, the MEW and LCEC launched an EOI to install three PV farms of 100 MWp capacity combined with a minimum storage capacity of 70 MWh each. The project is considered to be one of the largest of its kind and constituted an important milestone for the renewable energy sector in Lebanon. The EOI was initiated in March 2018, receiving 75 offers in July by 148 companies from 33 countries. The offered capacity reached 4 268 MWp, while the required capacity was only 300 MWp. Figure 23 shows the distribution of capacities per region, where the highest potential for solar PV is in the Bekaa region, for the reasons explained above.

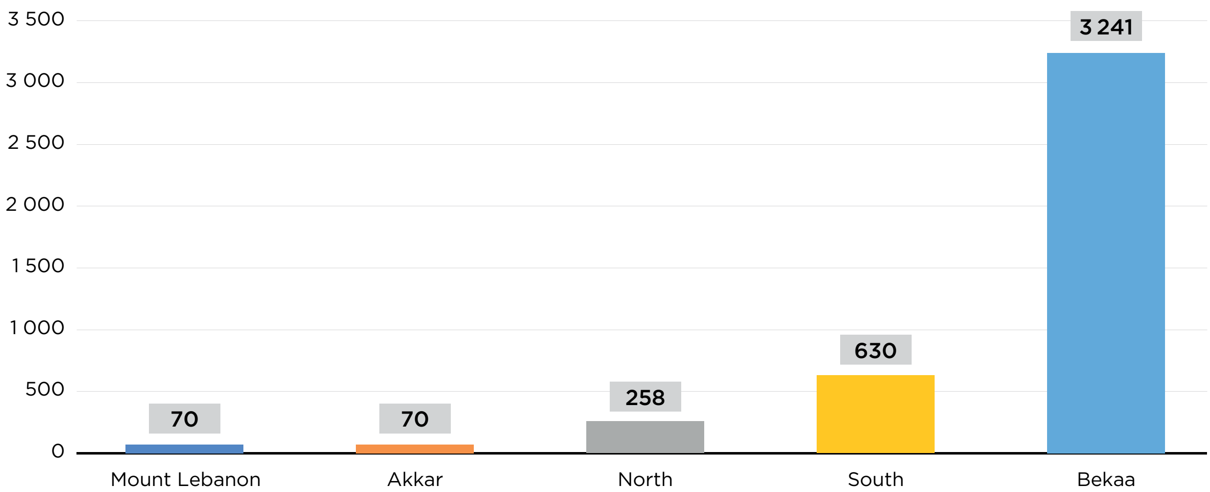
The MEW and LCEC are preparing for the launch of the second round of PV auctions to install 24 farms with a total capacity of 240–360 MWp before the end of 2020. Moreover, the European Bank for Reconstruction and Development (EBRD) has launched a feasibility study for a solar PV project with a capacity of 300–500 MW in the Tufail region based on a study from the American University in Beirut (AUB) that has identified 10–15 km^2 of land with high solar radiation which would be suitable for solar projects (AUB, 2019).[2]

Figure 22: Percentage of offers per region in response to the EOI of the first round of PV projects



Source: LCEC, 2019b

Figure 23: Offered capacities per region in response to the EOI of the first round of PV projects with storage



Source: LCEC, 2019b

2 Building on the AUB study, the National Center for Scientific Research (CNRS) and the Lebanese Foundation for Renewable Energy (LFRE), have developed a detailed mapping exercise. The analysis highlighted several sites with a combined potential capacity approximated at 4860 MWp, including Tfail (630 MWp), Mikrak (380 MWp), Al Ain (150 MWp), Maqné (1150 MWp), Harbata (850 MWp) and Hermel (1700 MWp).

ii. Distributed solar PV

Distributed solar PV, as defined by the NREAP, refers to PV systems installed to satisfy the local demand of a specific consumer or group of consumers. Distributed solar potential is hard to estimate, given the complex procedures for evaluating the capacity for rooftop installations. A project funded by the National Council for Scientific Research estimated the available rooftop area to be between 30% and 80% of the total rooftop area in Beirut – sufficient area to provide between 13% and 34% of the electricity needs of the capital.

Similar to large-scale PV, the potential for distributed PV systems remains far above the set targets for this technology in the NREAP of 100 MWp and 150 MWp in in 2020 and 2030, respectively.

As shown in Table 7, the project pipeline is unclear, particularly for plants being developed by the private sector, but given that these capacities have risen, an increase of 55 MWp can reasonably be estimated by 2020.

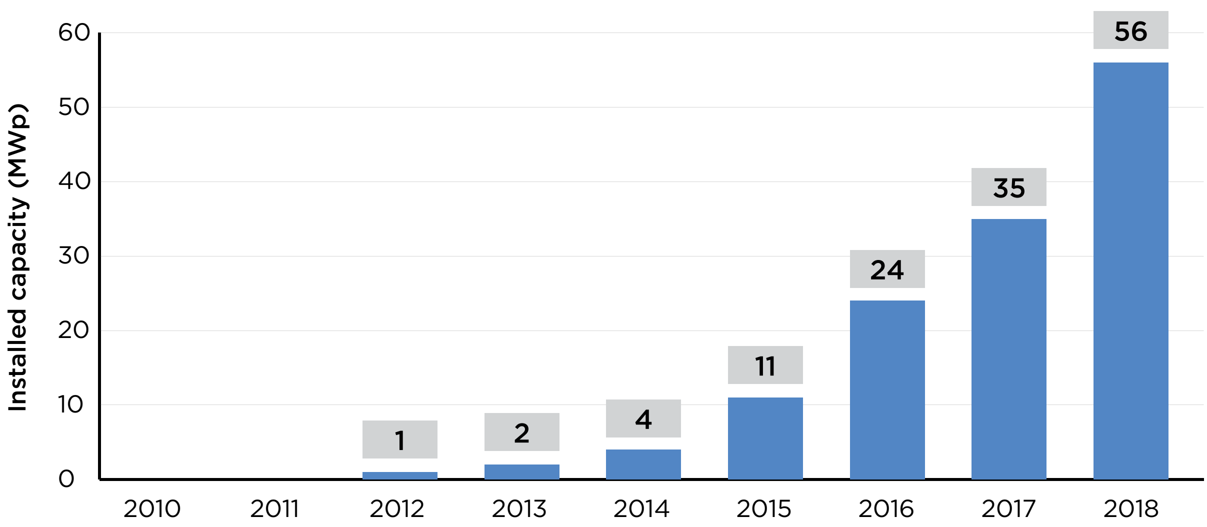
Driven by NEEREA Loans, the private sector has taken the lead in promoting distributed PV systems; Figure 24 shows the evolution of distributed PV systems starting at around 0.33 MWp in 2010 and rising to 56.37 MWp in 2018.

Table 7: Distributed PV targets and potential

	2020 target	2030 target*	Contracted capacity	Projects in the pipeline	Potential
Distributed PV	100 MWp	150 MWp	56.37 MWp	1.2 MWp (public sector) 56 MWp (private sector)	N/A

*Before Remap 2030 Scenario

Figure 24: Installed capacity of distributed PV solar systems



Source: DREG, 2017; LCEC, 2019b

NEEREA was created in collaboration with the central bank of Lebanon (BDL) to provide the private sector with long-term loans at low interest rates for distributed renewable energy applications or energy efficiency projects. NEEREA is the only green financing mechanism in the Arab region that has a loan ceiling of USD 10 million per project and offers low interest rates for periods up to 14 years – including a grace period of between six months and four years. These loans are provided directly through Lebanese commercial banks to end users.

The BDL has issued several circulars to ensure the consistency of NEEREA among all Lebanese commercial banks. As per Intermediate Circular 236, Lebanese commercial banks can free some of their required reserves at the central bank to finance NEEREA projects. Following Circular 236, the sustainability of the NEEREA financing mechanism was further secured by circulars 313, 318, 346 and 515, among others.

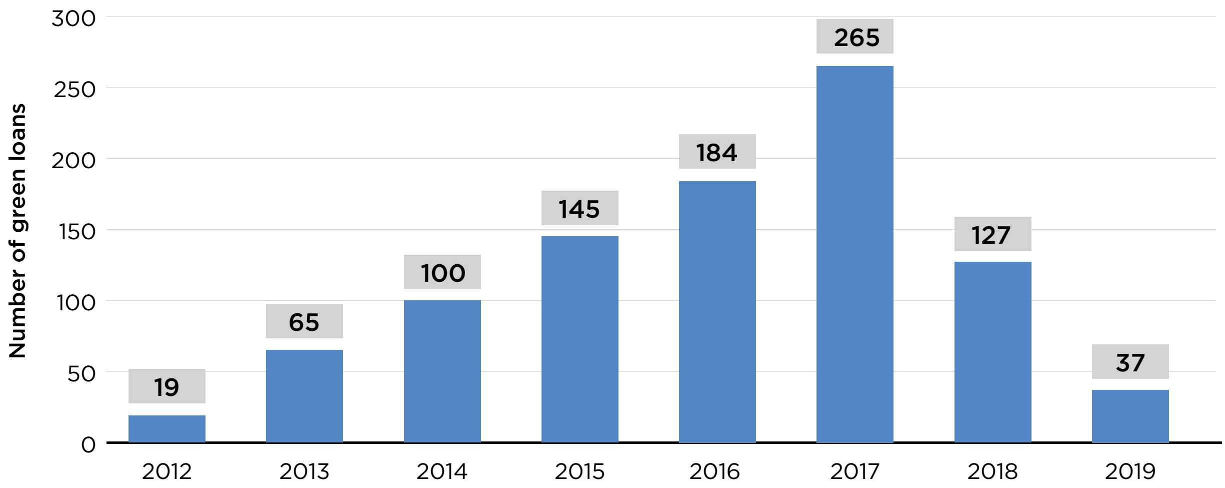
NEEREA has witnessed rapid growth and broad acceptance among the public, despite the barriers and instability in the energy sector. NEEREA loans are becoming increasingly popular products in the Lebanese banking sector, with more than 938 projects worth more than USD 560 million financed as of March 2019 (see Figure 25).

Out of the total number of projects funded by NEEREA, most of them included solar PV rooftop installations, reaching approximately 621 projects out of the 938 projects financed as of March 2019.

However, despite its successful implementation, the NEEREA financing mechanism has several constraints, particularly when applied to large-scale renewable energy projects, as it is designed to only finance renewable energy projects for own consumption and not for IPP purposes.

Following these private sector developments, the public sector launched a project to install PV systems in 10 public buildings. Table 8 presents the location of each installation, its size and status.

Figure 25: Number of green loans funded by NEEREA



Source: LCEC, 2019b

Table 8: Public sector projects: Scale and status

Location	Size (kW)	Status
Rooftop of the MEW building	150	Commissioned in 2018
Lebanese army buildings	310	Installed
Casino du Liban	300	Under evaluation
Wheat silos at Beirut Port	200	Under evaluation
Ministry of National Defence	150	Under bid preparation
Presidential palace	300	Under bid preparation
Lebanese University Faculty of Sciences campus and Ministry of Finance building	350	Under study

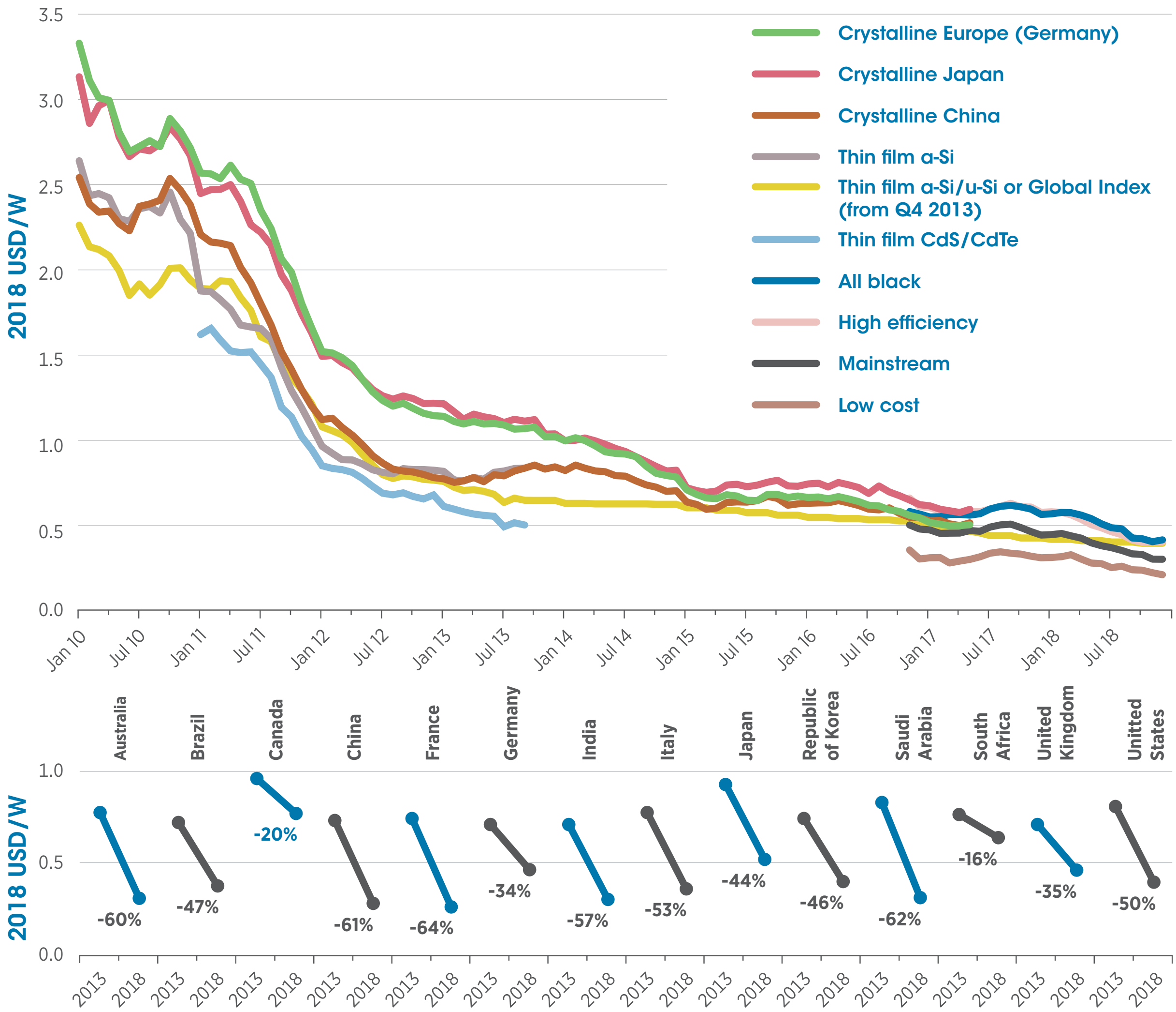
The MEW also installed around 4 000 PV of public street lighting systems with an installed total capacity of around 1.2 MWp. In addition, the Ministry of Education and Higher Education is also taking part in the development of distributed PV systems by installing 113 PV stations that include battery storage.

Another example of a private sector distributed PV system is the project implemented by the Council for Development and Reconstruction (CDR), where 800 PV street lighting poles were installed with a capacity of around 24 kWp, combined with 11 stations for PV pumping in the Baalbek region with a total capacity of 1.4 MWp.

The driving force behind all these initiatives has been the falling cost of technology. IRENA estimates that the price of solar PV modules has fallen by around 90% since the end of 2009 (IRENA, 2019b).

Figure 26 shows the average monthly European solar PV module price by technology and manufacturer in the period January 2010–July 2018 (top) and average yearly module prices by market in 2013 and 2018 (bottom), while Figure 27 shows the evolution of prices for distributed capacities within the Lebanese market by application.

Figure 26: Average monthly European solar PV module prices by module technology and manufacturer



Source: IRENA, 2019b

Notes: Jan 2010–Jul 2018 (top) and average yearly module prices by market in 2013 and 2018 (bottom).

Figure 27 shows that prices for most distributed PV applications have fallen worldwide. For hybrid applications – systems connected to the electricity grid with backup battery storage – prices have reached around USD 1 200 per kWp. Off-grid systems experienced the largest decrease in price of almost 46%, from above USD 5 000 per kWp in 2013 to around USD 3 000 in 2017.

For on-grid applications with batteries – systems connected to the grid with backup battery storage – prices in the market dropped from around USD 6 000 per kWp in 2013 to around USD 3 300 in 2017, representing a 39% decrease. Both systems have relatively higher prices than on-grid and solar pumping systems owing to their use of battery storage.

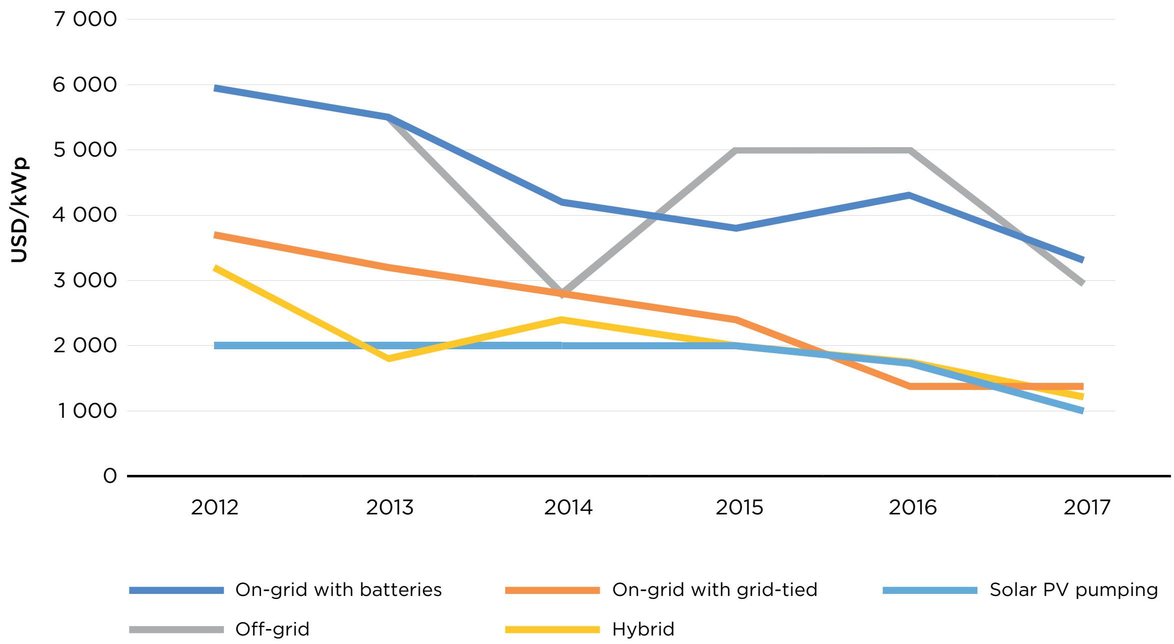
The price of on-grid with grid-tied systems fell from USD 3 700 per kWp in 2013 to 1 400 in 2017, marking an almost 57% decrease in price, while solar PV pumping experienced an expansion, leading to a reduction in prices of about 50% between 2014 and 2016, mainly due to the number of installations and their size. Moreover, all these prices were based on estimations made using NEEREA data that represents costs higher than regular market prices due to financing and study costs.

Other instruments supporting the deployment of distributed PV systems include public investments in government owned property and the net-metering scheme.

In 2011, net-metering[3] was introduced in Lebanon through a decision from the EDL board that was approved by the MEW, with the involvement of MEW advisors, the LCEC team, and the CEDRO project of the United Nations Development Programme (UNDP). [4]

Net-metering offered the first opportunity to connect renewable energy projects to the national grid. Although more than 50 projects are already connected to the network, several limitations exist due to the lack of meters at EDL and the manual methods used to calculate net excess amounts of monthly rollover for one year before returning the meter to zero.

Figure 27: Yearly average solar PV turnkey price by project type in Lebanon (USD/kWp)



Source: DREG, 2017

[3] Net metering is a financial agreement in which utility customers generate some of their own electricity and use a single meter to measure the net electricity bought from the utility. At various times, the customer will not use all the electricity generated. The excess is fed back into the grid and makes the meter run backwards. When the meter is read, it will usually show a net purchase from the utility. If, for some reason, the customer generated more electricity than was consumed that month and the meter shows a negative value, it will be read as zero or credited to the next month's bill. In effect, during a single billing period, the customer uses any excess generation to offset electricity that they would have had to purchase at the retail tariff.

[4] The main objective of CEDRO 4 is the application of renewable energy and energy efficiency systems and measures across Lebanon's several economic sectors (commercial, industrial, utility-scale, a demonstration project on a village scale, and bioenergy-sourced heating) and beneficiaries. Ultimately, CEDRO 4 will continue to benefit from the on-going assistance provided by the UNDP to the Government of Lebanon to develop and implement a national sustainable energy strategy to mitigate climate change, in line with the United Nations Development Assistance Framework (UNDAF) for Lebanon (2010–2014), and in line with the Millennium Development Goal 7 (MDG 7) to achieve environmental sustainability.

Currently, the LCEC in collaboration with MEW and with the support of the EBRD, are preparing a law allowing for the introduction of collective net metering and power wheeling which may help the development of renewables in Lebanon.

In addition to the efforts of local authorities and the private sector, the World Bank's Energy Sector Management Assistance Programme (ESMAP) has launched a global project to analyse rooftop solar potential based on stereo-satellite imagery in 14 cities across Africa, Asia, Latin America and the Middle East.

The goal of this data collection exercise is to create a methodology that could be replicated in any jurisdiction worldwide at low cost through machine learning efficiencies. The World Bank expressed an interest in leveraging IRENA's considerable experience gained from creating the rooftop solar city simulator (SolarCityEngine) for Kasese, Uganda and Zhangjiakou, China to collaborate on the 14-city project. Among these cities, the World Bank has identified Beirut as being key to implementation efforts.

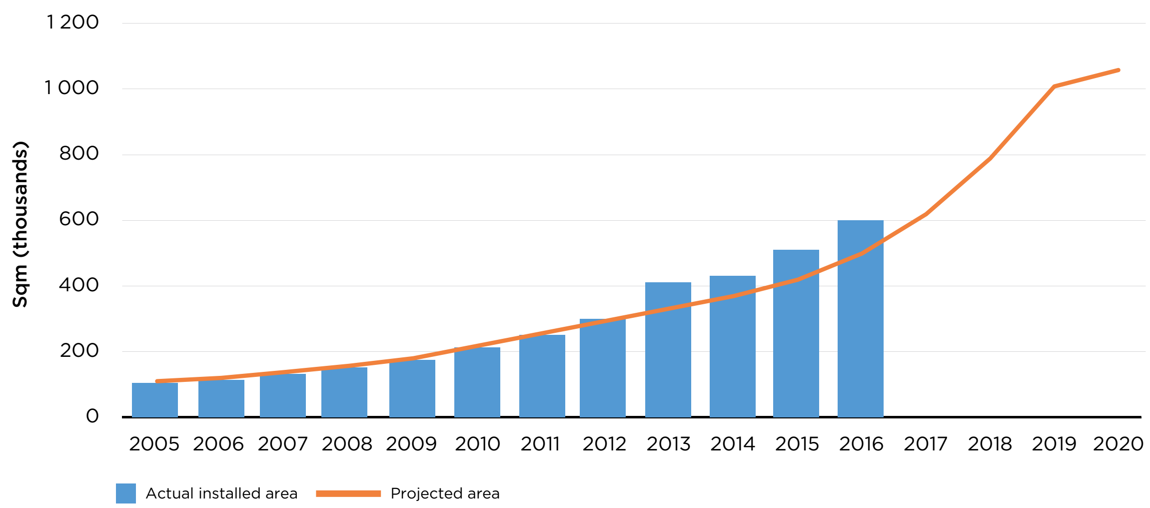
Solar water heaters

Solar water heaters (SWHs) were the first renewable energy application to be introduced in the last decade within the framework of energy efficiency under the first NREAP 2011–2015. Surveyed installations in the period 2005–2015 are shown in Figure 28.

As shown in Table 9, the targets in the NREAP 2016–2020 were 1 053 988 m² in 2020 and 1 716 835 m² in 2030. The evolution shown in Figure 28 reflects a declining growth trend, which will need to be taken into consideration in the coming years to reactivate the market and to regain the growth momentum of previous years. In this regard, Figure 28 shows a decrease in the financing of SWHs in the years 2012–2015, accompanied by a reduction in SWHs installed.

NEEREA loans and the incentives offered by the MEW – with USD 200 cashback on SWHs – have played an important role in the development of this market. Therefore, stakeholders will need to maintain incentives to keep boosting SWH proliferation, given its key role in achieving national energy targets.

Figure 28: Installed SWH collector areas: Actual versus projected



Source: LCEC, 2016

Table 9: SWH targets and potential

	2020 target	2030 target	Contracted capacity	Project in the pipeline	Potential
SWH	1 053 988 m²	1 716 835 m²	413 988 m² (2015)	N/A	N/A

Photograph: Shutterstock

4. THE RENEWABLE ENERGY ROADMAP (REMAP)

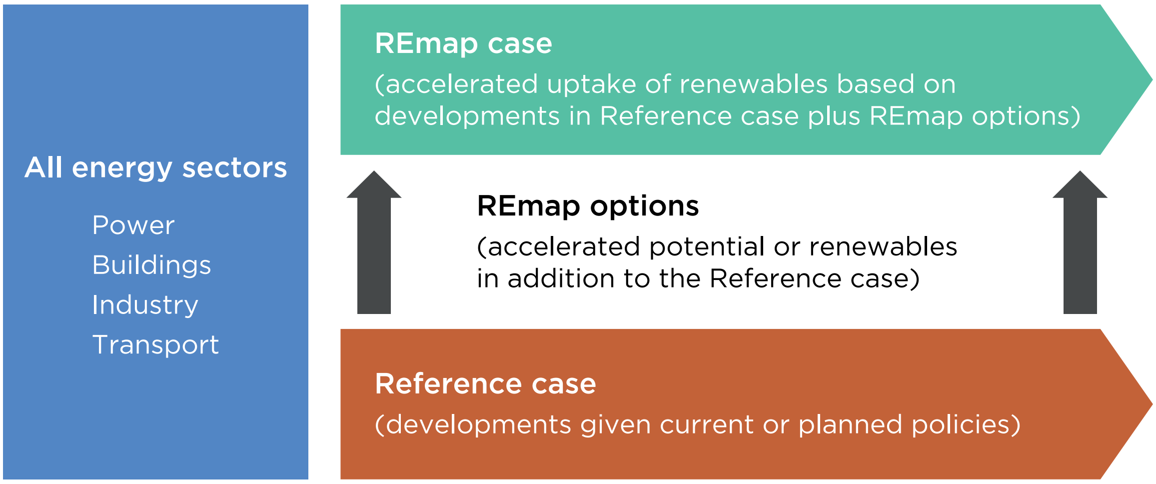
The previous sections have outlined the energy context in Lebanon and provided a view of how the country's energy landscape is likely to evolve over the coming years based on government plans and targets and the country's energy strategy, including the NREAP (both 2016–2020 and 2016–2020 editions). IRENA's REmap analysis, which is the focus of this section, provides an outlook for the potential of renewable energy in the country to 2030. It also highlights areas or sectors where the use of renewables could be scaled up.

This section first briefly presents developments that are likely to occur in what is termed the 'reference case 2030', which is based on current pipelined projects, market trends and forecasts. Next, it explores the accelerated potential of renewable energy beyond what is expected to occur in the reference case. These are called the 'REmap options', addressing the end-use sectors of industry, buildings and transport, and power generation. The resulting high-share-of-renewables case is called the 'REmap case'.

The REmap analysis for Lebanon extends to the year 2030, chosen as a standard medium-term assessment timeframe and a year featured in a variety of global targets, such as the United Nations-endorsed Sustainable Development Goals (SDGs). Figure 29 provides an overview of the key cases discussed in this chapter and the years that are highlighted.

The country analysis aligns with global sustainable development goals

Figure 29: Overview of the REmap approach



The steps involved in the REmap analysis for Lebanon presented in this chapter include:

- The definition of a base year selected to be the year 2014 due to data availability.
- The definition of a reference case 2030.
- The definition of a REmap case 2030.

A reference case 2030 is developed to present a view of a baseline scenario. This case represents possible developments in the energy system given the existing measures to support renewable energy deployment in Lebanon. The reconciled energy balance for the base-year 2014 is projected to develop the reference case for 2030. The projections are essentially based on the most recent national plans and commitments of the Lebanese government, including the NREAP (2016–2020), the second NEEAP (2016–2020) and pipelined renewable energy projects. Following a sectorial bottom-up approach, the reference case is built by projecting each energy carrier under each sector presented in the base year, in line with corresponding planned national projects and policies.

Based on the reference case, additional renewable energy deployment options are assessed. These are called REmap options and are based in part on country consultation, including analysis by energy experts from LCEC and consultations via workshops with Lebanese experts. The result of this option analysis is the REmap case, which details the potential of renewables and what this implies in terms of technological developments, including costs and benefits. Notably, the REmap case also provides a view of where the additional potential of renewable energy outside the power sector lies; i.e. in the end-use sectors of buildings, industry and transport, and for energy services related to heat, fuels and other direct uses.

The REmap case is built from the reference case to reach a 30% renewable energy share in the total consumption of electricity in 2030 by mapping the projected demand for electricity in the end-use sectors. This REmap analysis focuses primarily on the power sector due to the relatively large potential of renewables. It also proposes a synergy between renewable technologies in both the transport and building sectors from one side, and energy efficiency measures in the buildings and industry sectors on the other. The detailed analysis and findings for both the reference case and the REmap case will be discussed below.

End-use sectors

The starting point of the analysis is to estimate the energy demand in three main end-use sectors, namely, buildings, transport and industry. Demand projections are estimated starting from the energy balance of the base-year 2014 and use compound annual growth rates (CAGRs) for the different energy carriers in each end-use sector. The agricultural sector was not explicitly considered in the analysis as most of the energy demand in this sector is captured under fuels for transport, and due to the lack of more detailed information of other energy uses.

Renewable energy laws require an appropriate institutional framework and administrative capacity, including an independent regulator

Buildings

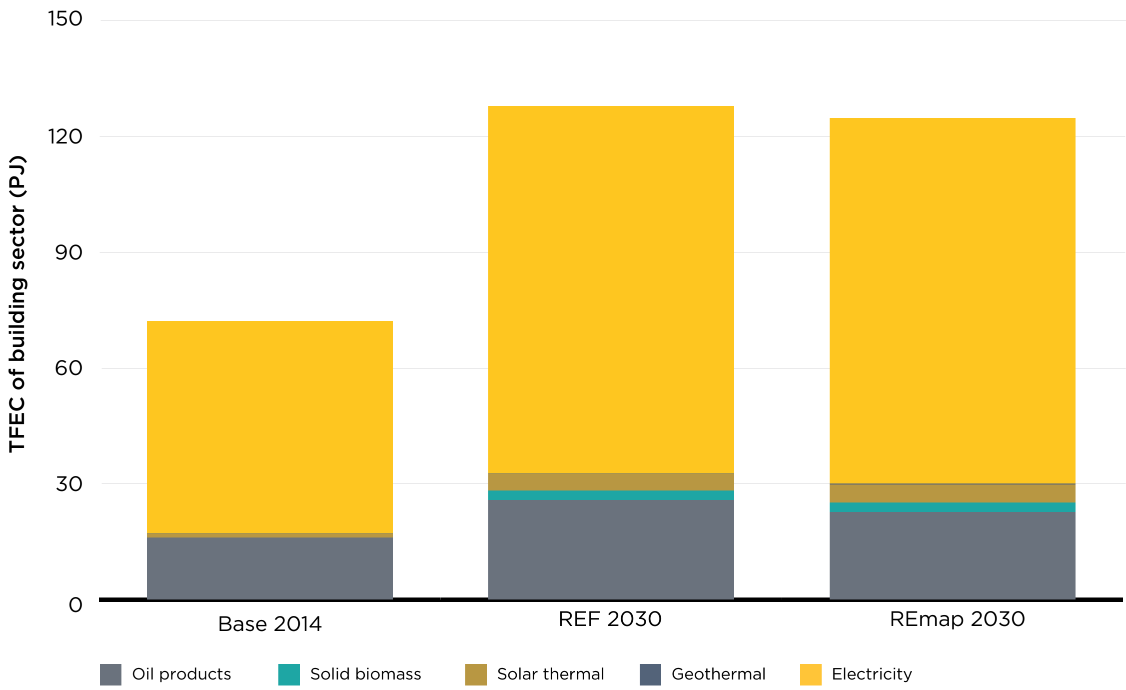
In the buildings sector, final energy consumption grows from 72 petajoules (PJ) in the base year to 128 PJ in the reference case, mainly driven by electricity consumption which grows from 55 PJ in the base year to 95 PJ in the reference case. Oil and oil products come in second place and grow from 16 PJ in the base year to 26 PJ in the reference case.

In the reference case, the existing plans and policies include energy efficiency measures and an increase in solar water heater implementation. The deployment of solar thermal technologies grows from 0.99 PJ in the base year to 4.16 PJ in the reference case. Another significant difference between the reference case and the base year is an increase in biomass consumption for space heating which rises from nearly zero in the base year to 2.53 PJ in the reference case. The direct renewable energy share[5] in final energy consumption in buildings grows from 1.4% in the base year to 5.4% in the reference case.

In addition to the measures already included in the existing plans and policies, the REmap case proposes a reduction in the final energy consumption of oil and oil products from 26 PJ in the reference case to 23 PJ in the REmap case by the promotion of electric cooking and heat pumps for water and space heating.

Despite adding electricity demand through the use of heat pumps and electric cooking, electricity consumption remains roughly the same at 95 PJ in both the reference case and in the REmap case due to the estimated energy efficiency improvements in new buildings, the additional promotion of SWHs, and high energy efficient heat pumps replacing electric boilers and heaters. Therefore, the share of renewables in the final energy consumption of the buildings sector increases from 5.4% in the Reference case to 6% in the REmap case.

Figure 30: Final energy consumption in buildings (PJ)



[5] Renewable energy share in this context is defined as the ratio of the renewable energy used to the total energy used, including only direct uses of renewable energy. This does not include the share of electricity coming from renewable sources and does not include solar PV units, which are accounted in the power sector.

Transport

In the reference case, the demand for transport services experiences a significant increase, mainly driven by population growth. The final energy consumption of oil and oil products in transport grows from 97 PJ in the base year to 130 PJ in the reference case. Due to the lack of clear plans for public transport and alternative fuels in the reference case, the demand increase is assumed to be met by oil and oil products.

In the REmap case, 2 PJ of biofuels and 0.46 PJ of electric vehicles are introduced. This translates into a modest but promising renewable share of 1.7% of final energy consumption in the transport sector and reduces the consumption of oil and oil products from 130 PJ to 128 PJ. The use of biofuels corresponds to a 5% volume-based mix of bioethanol – mainly imported – in gasoline used by passenger cars, which could potentially also bring cost savings from the replacement of fossil-based octane enhancers.

The deployment of electric vehicles corresponds to shifting 3% of the passenger kilometre (pKm) of passenger cars to electric vehicles. The introduction of electric vehicles leads to a reduction in the final energy consumption in transport, despite the growth in demand for transport services. This is mainly due to the energy efficiency improvements that result from electric vehicles compared to internal combustion engined vehicles.

Introducing electric vehicles would increase efficiency and reduce overall energy consumption for transport

Figure 31: Final energy consumption in transport (PJ)

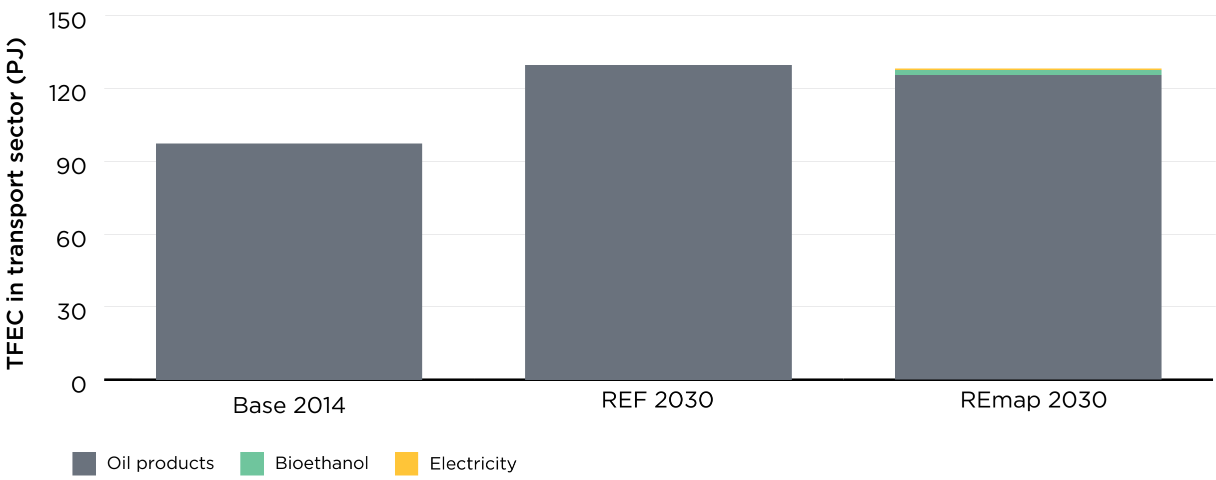


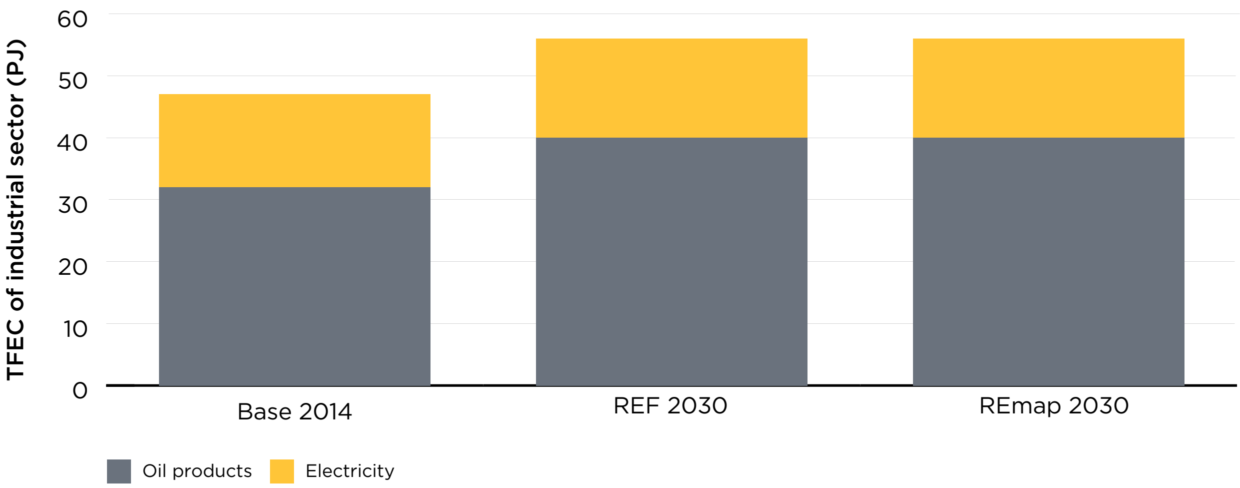
Table 10: REmap scenario for transport

Transport	Base 2014	REF 2030	REMAP 2030
Oil products (PJ)	97.2	129.7	125.4
Bioethanol (PJ)	0.0	0.0	2.2
Electricity (PJ)	0.0	0.0	0.5

Industry

The Lebanese industrial sector in general has not experienced significant growth in recent years. Based on available data, the annual growth rate for thermal and electrical consumption is considered to be 0.1% for all industries except for the cement industry, where an annual growth of around 2.4% in cement deliveries was detected.[6] Accordingly, the growth of final energy consumption in industry is mainly driven by cement production. The consumption of oil and oil products for thermal purposes grows from 32 PJ in the base year to around 40 PJ both in the reference and REmap cases, while electricity consumption grows from 15 PJ in the base year to 16 PJ in both the reference and REmap cases.

Figure 32: Final energy consumption in industry (PJ)



[6] This is based on cement delivery statistics obtained from the central bank of Lebanon. Cement deliveries are assumed to reflect the domestic production from cement plants in Lebanon.

TOTAL FINAL ENERGY CONSUMPTION (TFEC)

The sum of final energy consumption in the buildings, transport and industry sectors results in the total final energy consumption (TFEC). Figure 33 shows the evolution of the total final energy consumption in the end-use sectors for the base year 2014, the reference case and the REmap Case. The final energy consumption per usage is detailed for the three cases in Figure 34.

In the base year, the industrial sector, led by the cement industry, has a share of 21.5% in TFEC. This is followed by the buildings sector at 33.5%, and the transport sector at 45%. In the reference case, the transport sector leads with the highest share of 41.3% in TFEC, followed by the building sector at 40.7%, and the industrial sector at 18%. Figure 35 shows that the shares remain roughly the same in the REmap case.

Figure 33: Total final energy consumption by end-use sector (PJ)

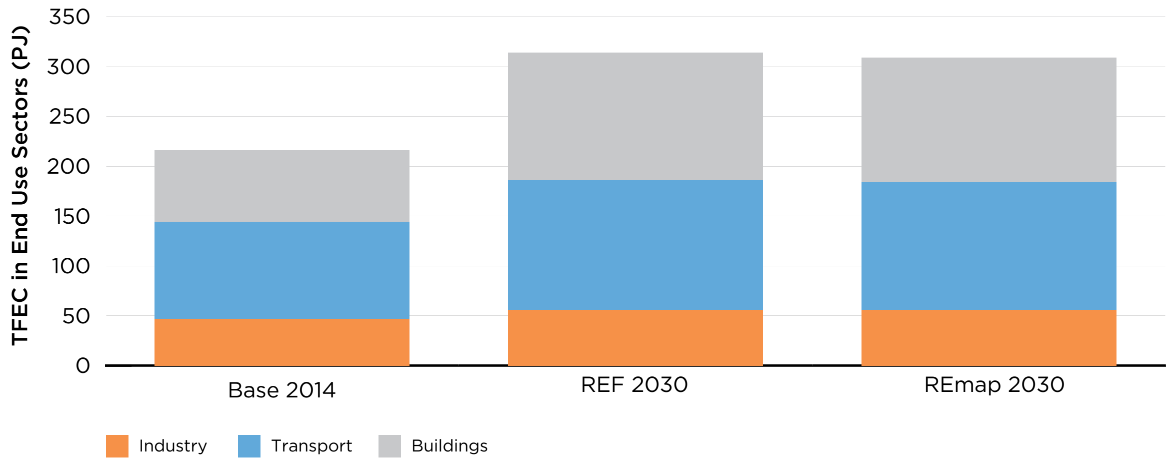


Figure 34: Details of TFEC in end-use sectors (PJ)

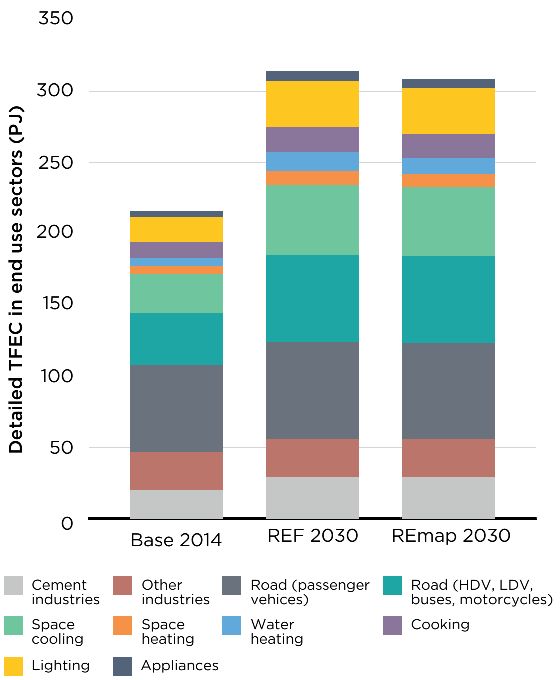
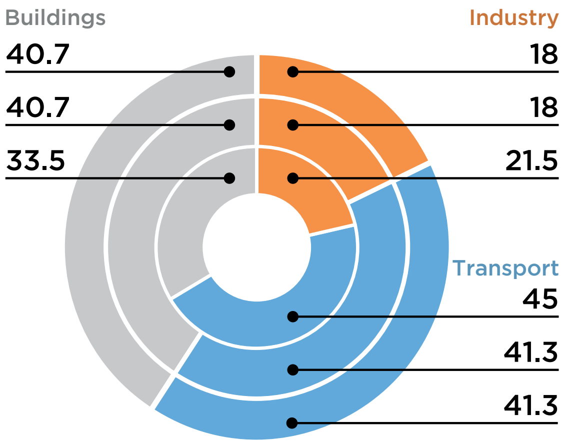


Figure 35: Shares of TFEC in end-use sectors (%)



The power sector

Given the base case and the projections for electricity demand in industry, transport and buildings discussed above, the demand for electricity grows accordingly from 70 PJ in the base year to 111 PJ in the reference case. In the REmap case, the consumption of electricity is also around 111 PJ, almost the same as in the reference case. The energy mix in the REmap case proposed in the following sections will meet this demand of 111 PJ.

The updated policy paper for the electricity sector considers a CAGR of 3% coupled with a drop of 8% in the total energy demand assumed in 2020 after the expected tariff increase. To meet that demand, the projection of the installed capacity of grid integrated renewables is given a priority due to the large potential in question.

Transmission and distribution losses are assumed to improve significantly both in the reference case and in the REmap case, moving from 16.5% in losses in the base year to 8% in the reference case and the REmap case. These improvements would be the result of the much-needed investments in the transmission and distribution network that are deemed to take place in the reference case.

Wind

Following the signature of the first wind energy PPA in the country, the first wind farm of 226 MW paved the way for another wind farm project of 200–400 MW under the same PPP scheme. Accordingly, the pipeline of projects for wind energy suggest that the total installed capacity of wind farms would reach around 626 MW in the reference case. To keep a diversified mix of renewables and considering the feasibility of the proposed targets, the total installed capacity of wind farms was determined to be 1 000 MW in the REmap case, which is less than the 1 500 MW cap for the total national feasible potential for that resource. Again, in terms of electricity, the generation provided by wind farms in the country experiences a tremendous growth from almost nothing in the base year to 1 817 GWh in the reference case and 2 655 GWh in the REmap case.

Hydropower

With the launch of hydro EOIs, the Ministry of Energy and Water has also reserved an important share for hydro resources. In fact, 25 economically viable sites have been identified with a potential of 233 MW in a run-of-river scheme or 315 MW in a peak scheme. Hence, by topping up the capacities of some of the 25 new sites through the corresponding EOI to the existing 286 MW, the total installed capacity of hydro power plants is expected to reach around 601 MW in the reference case and in the REmap case – assuming that all the implemented new hydro will be under the peak scheme. Revamping of old hydro plants is proposed to raise their energy production by 25% in the reference and REmap cases. Therefore, the electricity generated by hydro resources in the country experiences a noticeable growth from 425 GWh in the base year to 1 749 GWh in both the reference and REmap cases.

Biomass

Despite having a great potential detailed in the national bioenergy strategy for Lebanon, the reference case remains conservative in this area due to multiple complexities and local constraints. Nevertheless, the reference case dedicates a total installed capacity of 8 MW for bioenergy, specifically biogas generation from landfill municipal solid waste (MSW) used solely for electricity generation. The REmap case suggests another modest 5 MW on top of that from municipal wastewater treatment, leading to a total installed capacity of 13 MW from biogas power plants and a total electricity generation of around 100 GWh in the REmap case. Notably, the local biogas generated is used exclusively for generating electricity

Solar

In the reference case, targeted solar PV capacity is expected to reach 1 030 MW, which corresponds to the major pipelined projects, all primarily based on public–private partnership (PPP) models. On top of that, the estimated installed capacity of decentralised solar PV projects, mainly driven by national financing mechanisms such as NEEREA, is expected to reach 150 MW. Another major solar related technology, CSP with storage, is expected to reach a total installed capacity of 100 MW on the same timeline. Accordingly, the total installed capacity of solar PV in terms of grid integrated farms, including PV with storage, decentralised projects and CSP is expected to reach 1 280 MW in the proposed reference case.

In the REmap case, the total proposed capacity for solar PV was determined to meet the 30% renewable share in electricity consumption after the capacities for hydro, biogas and wind were determined as explained above. Government targets for hydro have already been set to develop all the economically viable locations in the country as detailed above. Wind energy was considered earlier to keep a diversified renewable mix and to promote additional investments in that field. However, the energy needed to reach the 30% target is covered by solar resources due to its large resource potential, lower cost of energy and relatively easier grid integration process. Accordingly, the total proposed capacity in the REmap case for solar is set at 3 100 MW, divided between 2 500 MW of solar PV farms, 500 MW of decentralised solar PV and 100 MW of CSP, assuming the market can achieve the decentralised solar PV target.

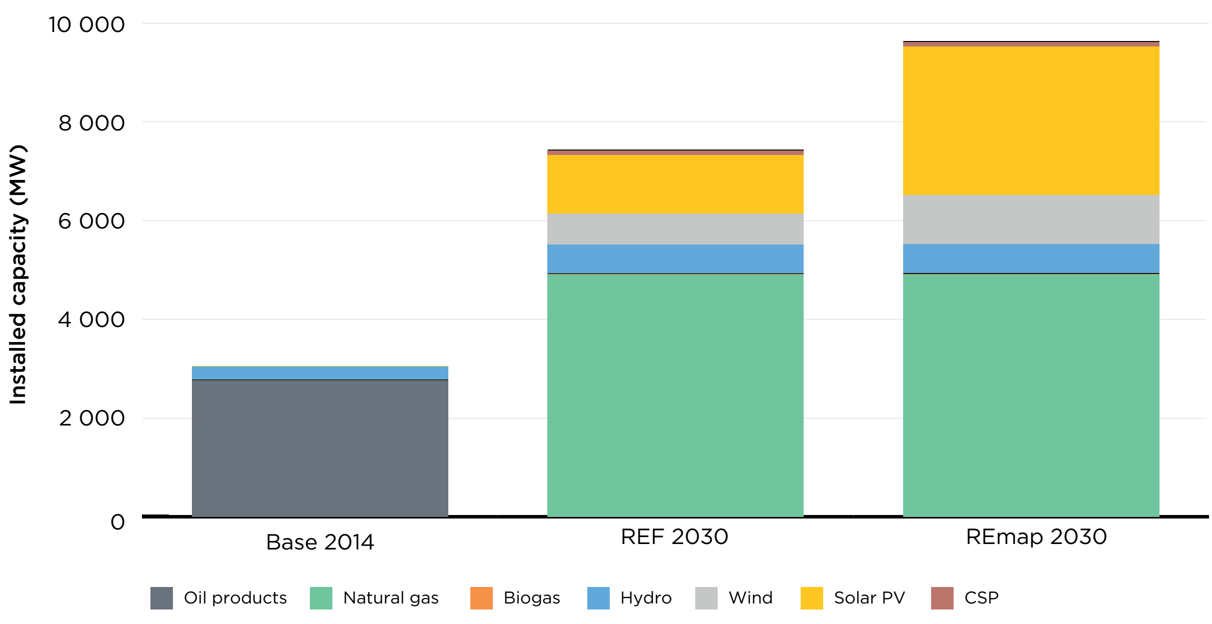
In terms of electricity, the generation provided by solar PV resources in the country is expected to experience tremendous growth from only 6 GWh in the base year to 2 049 GWh in the reference case, and 5 210 GWh in the REmap case. For CSP, the amount of electricity expected to be generated from the corresponding projects is the same in both the reference and REmap cases and is estimated to be around 395 GWh, assuming it is coupled with energy storage facilities.

Installed capacity and electricity generation

Accordingly, the reference case results in a total installed capacity of 2 515 MW from renewables compared with a total installed capacity of 4 909 MW from conventional centralised generation. The REmap case goes beyond this and proposes a total installed capacity of around 4 700 MW from renewables, led by solar PV. The corresponding details are shown in Figure 36, noting that the reference and REmap cases consider shifting all conventional power plants to natural gas, as per the updated policy paper. Notably, the REmap case identified a potential reduction in installed conventional capacity.

If renewables are given a priority in generation, conventional units will have to ramp down and satisfy the remaining demand for electricity. Accordingly, the amount of conventional installed capacity can be potentially reduced – all else being equal; however, this is subject to a detailed dynamic stability analysis to ensure that the system will remain stable in the worst possible case.

Figure 36: Installed capacities of power plants by technology (MW)



The electricity generation resulting from a capacity factor-based analysis, combined with several national studies, is shown in Figure 37. The electricity output from renewables in the reference case results in around 6 000 GWh or 18.11% of a total of 33 500 GWh. In the REmap case, the total electricity generated by renewables is around 10 100 GWh or 30.17% of a total of 33 500 GWh, as detailed in the following charts.

Renewable power generation could take priority, with conventional units gradually ramping down

Figure 37: Electricity generation by source (GWh)

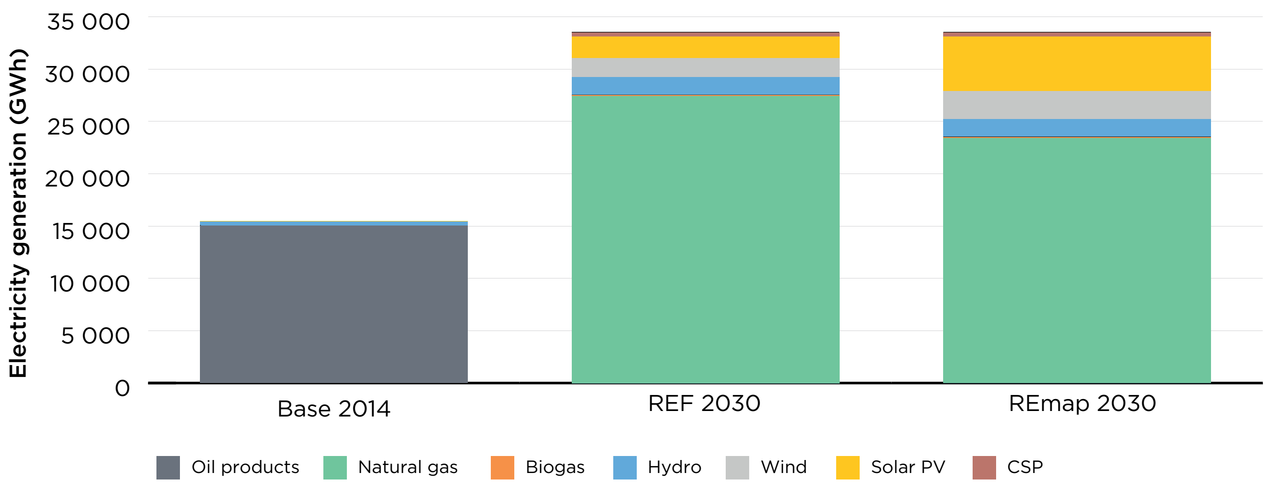
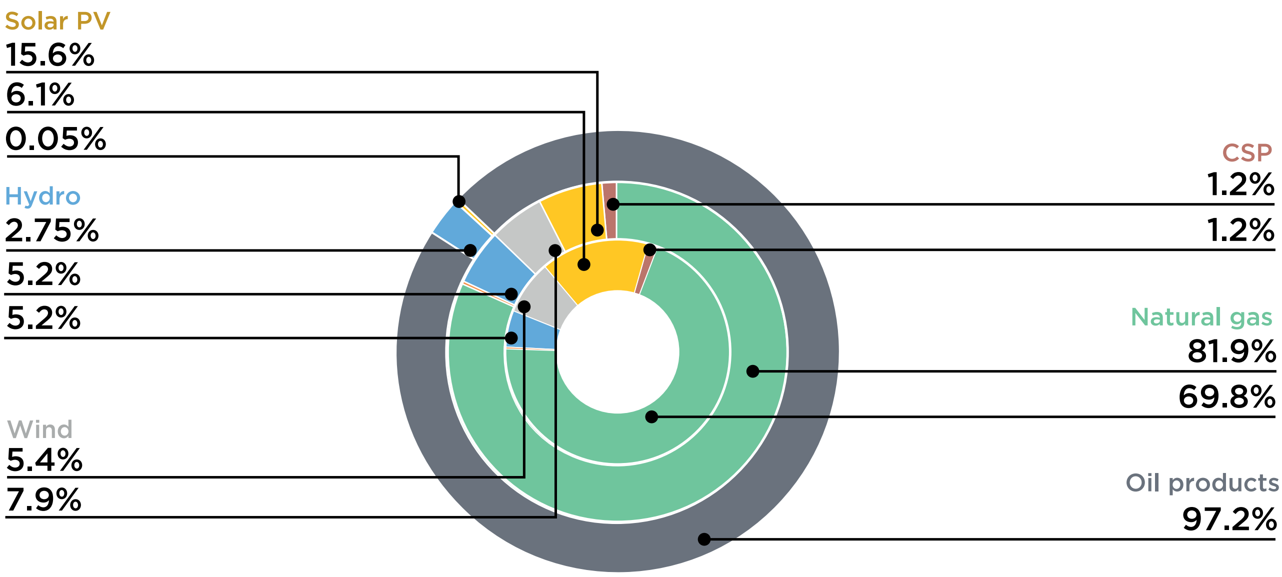


Figure 38: Shares of electricity generation by source (%)

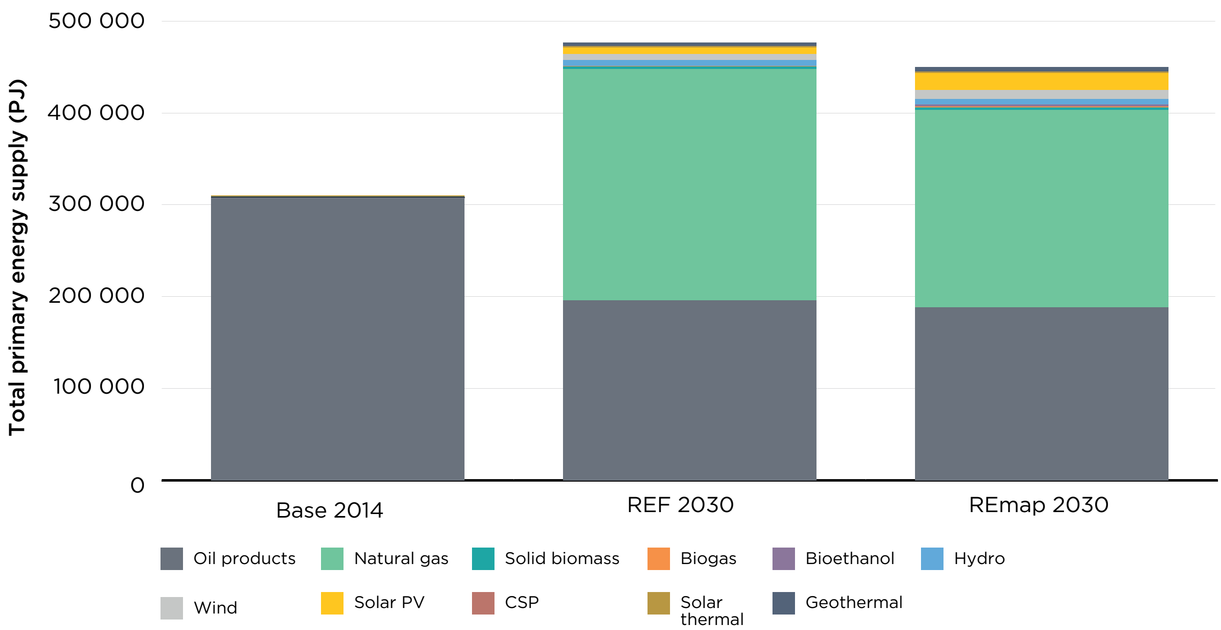


TOTAL PRIMARY ENERGY SUPPLY (TPES)

The results of the demand projections in the end-use sectors described above and the primary energy demand in the power sector indicate that TPES in Lebanon is expected to increase in the reference case, as shown in Figure 39. The increase in energy demand results in a CAGR of around 2.7% for the total primary energy supply from 2014 to 2030. In the reference case, the TPES rises from around 311 PJ in 2014 to 477 PJ in 2030. The total demand for fossil fuels grows from 308 PJ in 2014 to around 449 PJ in 2030, reflecting a growth rate of 2.4% per year.

For the REmap case, the CAGR for the TPES drops to 2.3%, where TPES is reduced from 477 PJ in the reference case to 450 PJ in the REmap Case, mainly due to synergies between renewable energy, electrification[7] and energy efficiency. The total demand for fossil fuels is reduced from 448 PJ to around 404 PJ, reflecting a growth rate of 1.7% per year from the base year. Figure 39 summarises and compares the TPES between the base year, the reference case and the REmap case. The REmap case also reduces the growth in the TPES and increases both the quantities and the share of renewables in the target year. The share of renewables in TPES increases from 6.1% in the reference case to 10.4% in the REmap case.

Figure 39: Total primary energy supply by source (PJ)



[7] Electrification in this context means the replacement of fuels by electricity in final energy consumption

Renewable energy shares

The shares of renewable energy that result from the analysis are presented in Table 11 and Figure 40. The renewable energy policy target of Lebanon is based on the share of renewable energy in electricity consumed. The REmap case is consistent with the target of 30% of renewables in electricity consumed in 2030. The share of renewables, including the renewable share of electricity, in TFEC increases from the base year in the reference case and the REmap case.

The increase in the share of renewables in TFEC is a result of the electrification of end-use sectors using renewable electricity, as opposed to direct use of renewables. This approach not only simplifies the challenge of increasing renewables penetration (since it is based on a single carrier – electricity – which is very flexible and can be used in diverse end-use applications) but also provides significant improvements in energy efficiency on the end-use side.

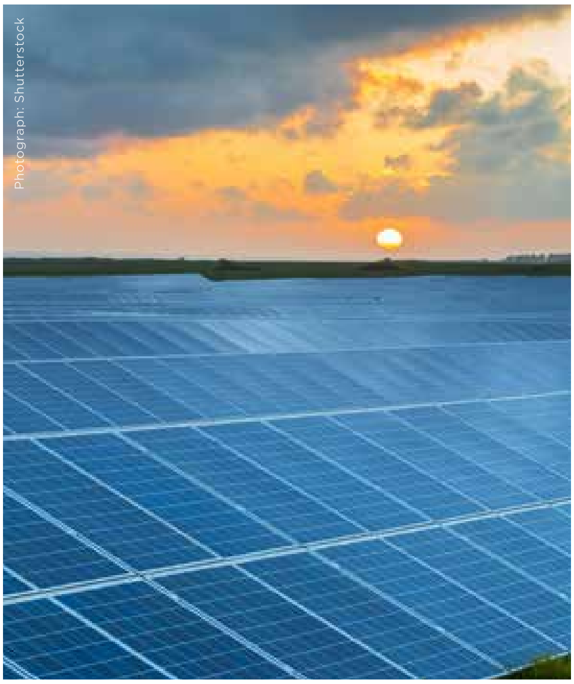
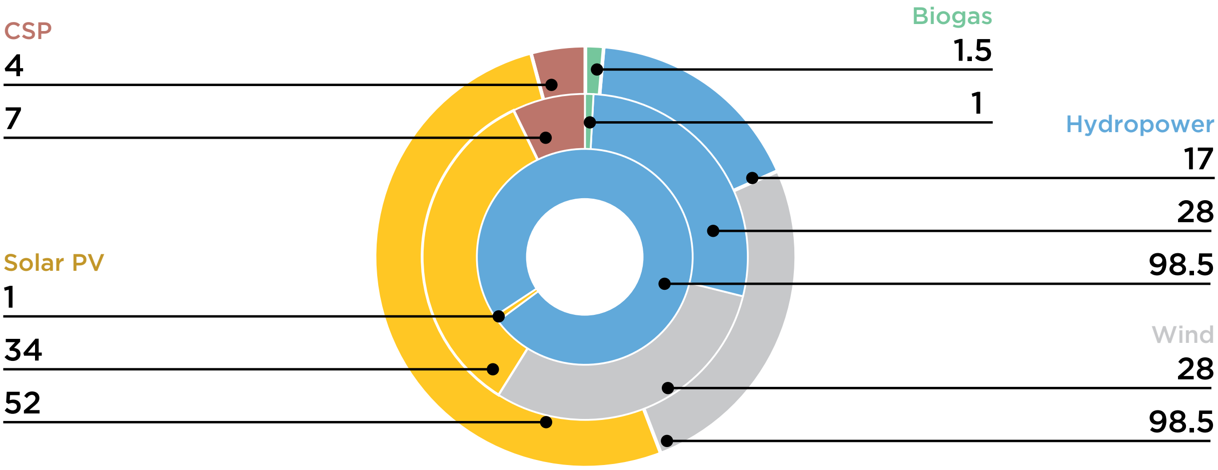


Table 11: Evolution of the shares of renewable energy

	Base year (2014)	Reference case (2030)	REmap case (2030)
Policy target			
Share of RE in electricity consumed [8]	2.79%	18.11%	30.17%
Other shares			
Share of RE in TPES[9]	0.82%	6.10%	10.39%
Share of RE in TFEC[10]	1.37%	8.60%	13.97%

Figure 40: Percentage of electricity generation from renewable sources (%)



Inner circle: base year 2014; middle circle: reference case 2030; outer circle: REmap case 2030.

[8] Expressed in GWh.

[9] TPES and TFEC expressed in PJ.

[10] Including the electricity consumed in end-use sectors and supplied from a renewable source.

REMAP COSTS AND BENEFITS

This section focuses on the assessment of the costs and benefits of the different identified REmap options that were proposed previously in this report, with a special focus on the power sector. The methodology consists of evaluating different indicators in that context, which include costs savings, CO_2 emissions avoided, and associated externalities such as the social cost of emissions. Infrastructure upgrades are undoubtedly needed to safely implement the REmap option. These were not included in the analysis for the sake of simplicity, since the aim of this section is only to highlight the potential benefits rather than propose a detailed financial analysis.

Potential savings in the power sector

The cost of the total energy generated by the power sector in the reference case is compared to the total cost of energy generated in the REmap case – a necessary step to compute the true savings based on the same amount of produced energy. In other words, the same amount of energy would be generated by a different mix in the power sector in the REmap case following the substitution concept, and the associated benefits would be based on the difference in energy generated under each technology and its corresponding LCOE.

Since the costs and savings – largely related to fuel savings – correspond to the year 2030, the analysis proposes a set of scenarios linked to the potential savings between the suggested worst case and best-case scenarios. The considered variables in the sensitivity analysis are mainly: the discount rate affected by the economic situation and political stability; fuel cost; and the projected capital cost of renewable technologies in 2030. Several scenarios are discussed based on possible combinations of these variables. However, only those that reflect real local conditions are retained. Accordingly, worst-case, average-case and best-case scenarios were proposed.

The worst-case scenario would correspond to a low fuel price, high discount rate and high capital cost for renewables, which results in a low LCOE for conventional energy and high LCOE for renewable energy. On the other hand, the best-case scenario would correspond to a high fuel price, low discount rate and low capital cost for renewables, which results in a low LCOE for renewable energy and a high LCOE for conventional energy. The average-case scenario is proposed based on mid-values of the corresponding variables.

Therefore, the total cost of energy for both cases – reference 2030 and REmap 2030 – is estimated under each scenario by multiplying the amount of energy from each generation technology by the corresponding LCOE, with the same discount rate used for both conventional and renewable energy. The difference in each case would reflect the potential savings from the REmap case. The results suggest that the implementation of the REmap options in the power sector would save on average USD 249 million per year under the average-case scenario compared with the reference case, as shown in Table 12 below. The corresponding detailed LCOE under each scenario can be found in Annex 2.

Table 12 presents the potential savings in the REmap case in 2030 compared with the reference case in 2030. These savings consider only renewable energy technologies in the power sector that have different amounts of installed capacity in both cases. Hence, CSP and hydro are not accounted for in this context, since their installed capacity is the same in the reference and REmap cases. Power generation from decentralised solar PV is assumed to be supplied at zero cost, since it mainly comes from private investments on the end-user side. The results displayed in Table 12 are rounded to the nearest integer.

Ideally, the additional energy provided by renewables should replace the energy produced by the most expensive units based on their order of merit. Due to the variable nature of some renewable resources, however, renewable-based generation can have a relatively high degree of unpredictability and uncertainty. Renewables, therefore, cannot simply be assumed to replace existing units.

Renewable-based generation was given priority, regardless of time of day, considering that the stability of the system would be preserved and the difference between the total produced energy in the two cases would be considered instead of a technology-specific shift. A more in-depth study is, however, required to optimise the replacement of energy via unit commitment and economic load dispatch analysis coupled with specific local constraints and initial conditions.

In addition to cost savings in the power sector, initial savings from energy efficiency measures proposed in the REmap case are also identified. As expected, the buildings sector is the main source of these savings on the end-user side and has an aggregate total potential of around 377.42 GWh of electricity avoided – estimated to be equivalent to around USD 46.13 million of savings per year. These savings are already reflected in the power sector as shown in Table 12.

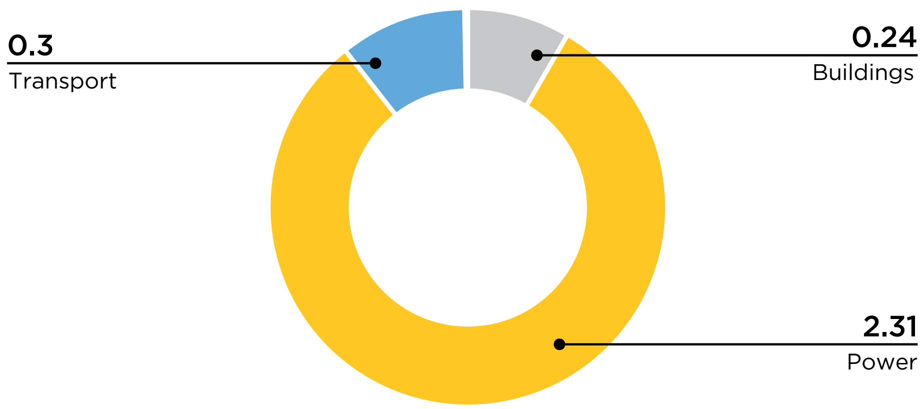
Table 12: Potential average savings in the power sector: Comparison between the REmap case 2030 and the reference case 2030

REF 2030	Capacity (MW)	Average LCOE (USD ¢/KWh)	Generation (GWh)	Cost (USD m)
Natural Gas	4 909	10.76	27 432	2 951
Wind	626	8.27	1 817	150
Hydropower	601	5.33	1 749	93
Solar PV[11]	1 030	4.47	1 789	80
Biogas	8	4.55	59	3
Total energy cost (USD million)				3 277
REmap 2030	**Capacity (MW)**	**Average LCOE (USD ¢/KWh)**	**Generation (GWh)**	**Cost (USD m)**
Natural Gas	4 909	10.76	23 393	2 517
Wind	1 000	8.27	2 655	219
Hydropower	601	5.33	1 749	93
Solar PV[12]	2 500	4.47	4 342	194
Biogas	13	4.55	99	5
Total energy cost (USD million)				3 028

Emissions reduction and externalities

The REmap case provides important benefits related to air pollution and social costs. In fact, the substitution of fossil fuel based energy by renewable energy would result in an emissions reduction, inherently improve air quality and reduce associated social costs. The results suggest that an estimated total of around 2.85 MT of CO_2 emissions and their associated monetary and social costs may be avoided by implementing the suggested REmap options as detailed in Figure 41. No important savings were proposed in the REmap case for the industrial sector, despite its importance, due to the lack of data.

Figure 41: Potential CO_2 emissions reduction in MT from REmap options



[11] Includes centralised solar PV only.
[12] Includes centralised solar PV only.

Associated costs and investments

The investments needed for the REmap case are identified with a focus on the power sector, which is the main 'game-changer'. The cost of each incremental MW of installed renewable capacity in the REmap case beyond the reference case was determined based on a high, medium and low CAPEX for each technology. The total investment needed to implement the REmap options in the power sector in comparison to the base year amounts to USD 6.67 billion for the medium case, as shown in Table 13.

The investment needed to implement the REmap options in comparison to the reference case – in other words the investment needed only for the additional amount of renewables – is estimated at around USD 2.2 billion, as shown in Table 13. This investment would be mainly financed through the private sector and international financing institutions through an IPP/PPP model. Again, these costs do not include the upgrades to infrastructure required to successfully implement the REmap options, which would demand a more in-depth analysis of capacity expansion with higher shares of renewables and grid stability. The results in Table 13 and Table 14 below are rounded to the nearest integer.

Additional costs were identified for the REmap options proposed for the end-use sectors. These expenses would mainly include subsidising the price of heat pumps to make them price competitive in the Lebanese market; providing additional incentives for the deployment of solar water heaters; and potentially reducing the import and/or registration taxes on electric vehicles, ideally financed through international grants for subsidised loans. Accordingly, the government would not incur any major investment costs to implement the Remap options in end-use sectors and would benefit simultaneously from the monetary equivalent of the potential energy substitution.

Investments in the power sector could be a game-changer in Lebanon's shift to renewables

Table 13: Overall required investments for REmap options in the power sector

Technology	Capacity (MW)	Cost high (USD bn)	Cost medium (USD bn)	Cost low (USD bn)
Wind	1 000	2.075	1.787	1.499
Hydropower	601	2.614	1.942	1.269
Solar PV[13]	2 500	3.750	2.578	1.406
Biogas	13	0.053	0.050	0.047
CSP	100	0.400	0.309	0.218
Total (USD billion)		8.89	6.67	4.43

Table 14: Additional required investments for REmap options compared to current plans in the power sector

Technology	Extra capacity (MW)	Cost high (USD bn)	Cost medium (USD bn)	Cost low (USD bn)
Wind	374	0.776	0.668	0.560
Solar PV[14]	1 470	2.205	1.516	0.827
Biogas	6	0.021	0.020	0.019
Total (USD billion)		3.00	2.20	1.41

13 Includes centralised solar PV only.
14 Includes centralised solar PV only.

Additional renewable energy benefits and drivers

The advantages of the Remap options are not only limited to the reduction of costs and emissions but also offer broader socio-economic and global benefits, such as the creation of new jobs and markets, the injection of cash inflows to the country, improved energy security through energy mix diversification, mitigation of oil bills, the promotion of domestic industries, and improved air quality.

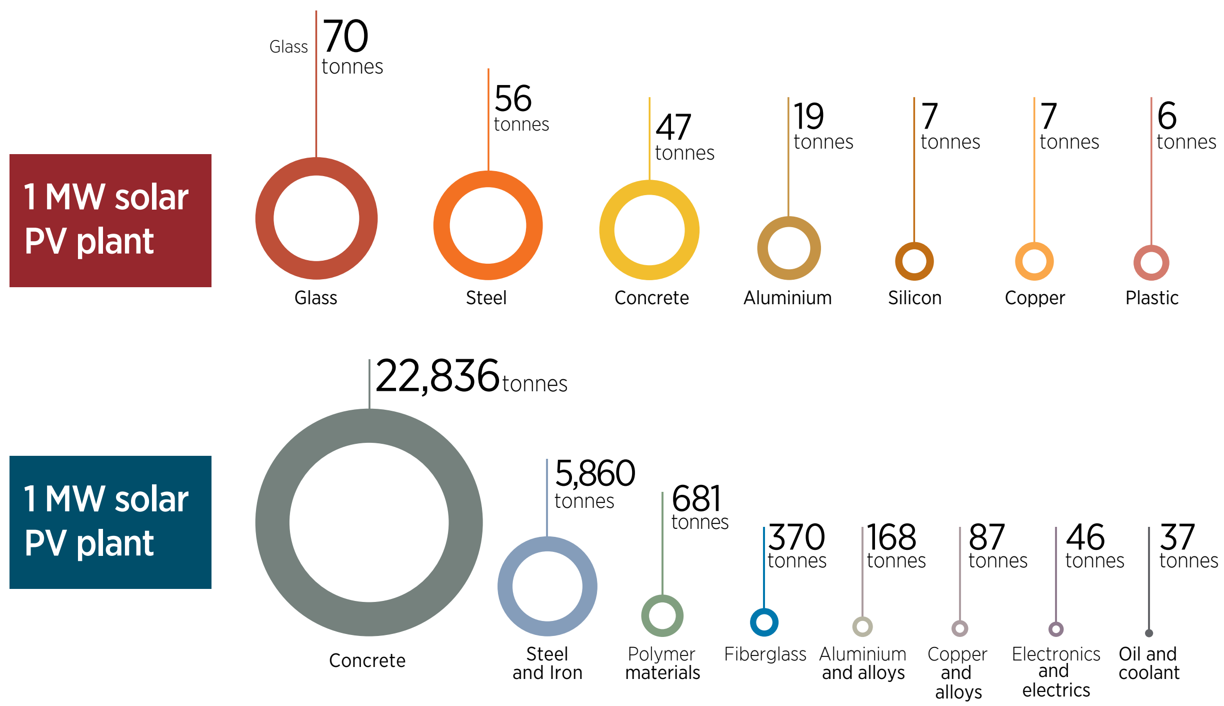
However, to design effective policies in support of value creation, policy makers require a thorough understanding of materials and labour requirements. IRENA's "Leveraging local capacity" report series examines these requirements in the solar PV and onshore wind industries (IRENA, 2017d; 2017b).

Figure 42 shows the main materials required by solar PV and onshore wind plants, and therefore indicates the kinds of industries most relevant to satisfy the inputs for renewable energy deployment. Maximising value creation from the development of a domestic solar PV industry, for example, requires leveraging capacities in industries such as glass, aluminium, silicon and semiconductors. Leveraging this capacity can provide expertise, raw materials and intermediary products for manufacturing PV components such as PV cells and modules, inverters, trackers, mounting structures and electrical equipment.

For a typical 50 megawatt (MW) onshore wind facility, almost 23 000 tonnes of concrete is needed for the foundations, and nearly 6 000 tonnes of steel and iron for the turbines and their foundations. For offshore wind the requirements are similar. Manufacturing the main components of a wind turbine requires specialised equipment as well as welding, lifting and painting machines that are used in other industries, such as construction. The foundations also require the use of specialised equipment including rolling, drilling and welding machinery. Special vessels and cranes are used to move these structures. Examining these requirements provides insights on industrial capabilities to be leveraged.

Power system investments could be financed through public-private partnerships

Figure 42: Materials required for a 1 MW solar PV plant and a 50 MW onshore wind plant



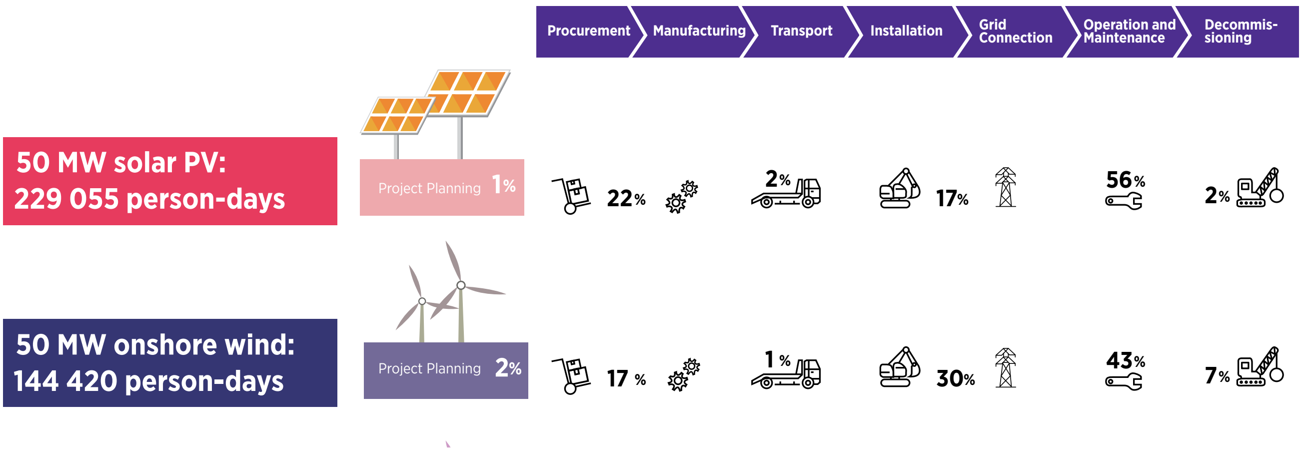
The "Leveraging local capacity" report series also generates valuable information for policy makers on the occupational and skill structure along the value chain. Figure 43 shows the labour requirement for solar PV plants and onshore wind farms.

For the development of a typical 50 MW solar PV project, a total of around 230 000 person-days is required from project planning to manufacturing, installing, operation and maintenance (O&M) as well as decommissioning. The highest labour requirements are in O&M (56%), followed by procurement and manufacturing (22%) and construction and installation (17%). In the procurement and manufacturing segment, factory workers and technicians represent 64% of the labour, followed by engineers (12%). In the O&M segment, construction workers account for 48% of the labour requirements, followed by safety experts (19%) and engineers (15%).

Similarly, for the development of a 50 MW onshore wind project, a total of 144 000 person-days is needed. The labour requirements are highest in O&M (43% of the total), followed by construction and installation (30%) and manufacturing (17%).

The additional benefits of renewables are summarised in Boxes 2 and 3.

Figure 43: Distribution of human resources and occupational requirements along the value chain (50 MW PV project; 50 MW onshore wind)



Based on IRENA analysis

Box 2 P2P blockchain-based trading

The technological advancements in the areas of P2P trading and blockchain promote the implementation of community-scale renewable energy systems which, in turn, can boost the number of small-scale decentralised solar PV systems in Lebanon. In fact, the market for this type of application is already opening up in Lebanon with the recent implementation of community-based net metering pilot projects which rely on hybrid solar PV systems.

P2P energy trading managed by the utility offers an important potential for demand side management and control, specifically when these PV systems are coupled with battery storage where the energy flows can be potentially directed as needed. If replicated on a large-scale, potential grid support functions can be also explored.

These technologies also offer the potential to analyse the recorded consumption patterns of the prosumers, and hence optimise the energy forecasts for both renewable energy generation and load duration curves. The utility or TSO could ideally operate the blockchain and hence track all the transactions made in all the connected devices and households, which would facilitate grid monitoring and operation.

In fact, many European TSOs are currently exploring the use of blockchain technology for energy demand response, measurement and verification, as well as for financial settlement. TSOs are also using blockchain in a pilot project to procure balancing services from behind-the-meter batteries. Locally, additional efforts are still needed to set the regulations and the business model for these promising technologies, which can play an enormous role in promoting small-scale decentralised renewable energy systems.

Box 3 Potential for electric mobility

Road transport for passengers in Lebanon has been a major daily issue for the past five years. The growing population and the influx of refugees, often having a personal car, has worsened both the congestion and the emissions problem in the country due to the lack of developed and organised public transport. Consequently, passenger cars are expected to remain one of the main means of everyday transport in Lebanon in the medium term.

Accordingly, and since the daily travelled distances are relatively short, the REmap analysis identified a potential role for electric mobility in Lebanon which could not only mitigate the emissions problem but also offer support to the grid. Admittedly, the introduction of electric mobility would eventually increase the demand for electricity, which is already a challenge in the local context. However, MEW plans for smart grids and smart charging technology, time-of-use pricing, fast technological advancements in the field and a solid regulatory framework could turn this challenge into a benefit and allow a higher potential for the introduction of additional renewables to the grid and the provision of both grid services and flexibility.

Potential grid service provisions via decentralised battery storage

Dynamic charging and time-of-use tariffs would allow advanced forms of multidirectional smart charging, including vehicle-to-grid and vehicle-to-building that would, in turn, provide more flexibility to the grid. This multidirectional advanced charging feature would permit a reshaping of the load duration curve through either filling and/or peak shifting or shaving. This feature would help the grid operator to manage congestion and reduce the reliance on expensive peak units. Several similar pilot projects have already been successfully tested by renowned grid integration experts around the world. Advanced smart charging could also mitigate the peak created by EVs under uncontrolled charging by adopting an over-night slow charging pattern. Many types of smart charging have been developed; however, more in-depth analysis would be needed to determine the most suitable option for the Lebanese context.

A major issue that should be considered would be the possible long waiting time for charging at the end-user level, which can be potentially mitigated via rooftop solar PV with adapted storage systems. This would create significant potential to integrate rooftop solar PV on existing filling stations and buildings in general, which can be retrofitted with a packaged solution to provide a charging service for EVs.

The deployment of EVs can also reduce the curtailment risk of variable renewable generation in the short-term by using the battery as a storage facility to compensate for the intermittency of renewables.

Therefore, adapting the charging cycle for EVs to the prevalent conditions of the power system and to the needs of the vehicle user would facilitate their integration, allow additional integration of renewables and reduce emissions.


Photograph: Shutterstock

5. CHALLENGES AND RECOMMENDATIONS

The main challenges facing the deployment of renewable energy in Lebanon are related to the country's institutional and regulatory framework, the availability of financing, and the state of resources, technology and infrastructure. This chapter discusses those challenges and proposes recommendations identified through the RRA process and REmap analysis.

INSTITUTIONAL AND REGULATORY FRAMEWORK

This report identifies the lack of a stable regulatory framework for renewable energy deployment and incomplete implementation of Law 462. Addressing this barrier would enhance the deployment of renewable energy resources for both large- and small-scale applications. Moreover, it would also help to attract more investments into the sector and create socio-economic benefits, including job creation.

Challenge A: Lack of a stable regulatory framework for renewable energy deployment and incomplete implementation of Law 462

Despite Lebanon's Copenhagen obligations, the Lebanese government has not provided any incentives for renewable energy on the legal level or distinguished between renewable and conventional energy sources, whereby they remain constrained by law 462/2002 and its amendments. The legal framework does not clearly lay out the role of renewables in the energy mix; the institutional set up does not define the roles and responsibilities of the different institutions (government, city and municipal); and the regulations do not explicitly stipulate the involvement of the private sector. Moreover, the sector faces potential conflicts with laws and regulations from other main sectors (e.g., real estate, agriculture and tourism). Since 2002, the renewable energy sector has been developing based on temporary amendments and loopholes in existing laws and regulations.

Recommendations:

- **Consider a new electricity law clarifying the role of renewable energy**

To address the existence of several laws governing renewable energy deployment, a more integrated and stable solution would be to establish a holistic electricity law encompassing renewable energy applications, thus ensuring a consistent legal framework for the renewable energy sector.

- **Establish an independent electricity regulatory authority**

As provided by law 462/2002, the Electricity Regulatory Authority (ERA) may allow for a clear and single access point for the private sector towards the electricity sector.

The existence of the ERA would pave the way for setting streamlined procedures for the licensing of new renewable energy projects. The government, formed in January 2019, pledged to solve this problem by establishing the ERA and by prolonging law 288/2014 for the intermediate period to allow for the continued development of the sector. In addition, establishing the ERA and defining the different licensing procedures may help define the roles and scope of the existing entities within the licensing and management processes, including: LCEC, MEW, EDL, PPMA, the Higher Council of Privatization and CoM.

Challenge B: Lack of sectoral and technology-specific renewable energy targets

In 2009, Lebanon set ambitious targets to meet 12% of its national primary energy mix with renewables by 2020 through defined targets of different renewable energy installations. In 2018, these targets were revised to 30% of renewables in the energy consumption mix. However, there is no clarity on the long-term vision of the energy transition, including the role of energy efficiency and conservation and the synergies with renewable energy. In this context, the targets are not clearly distributed among end-uses, consuming sectors or technologies.

Recommendations:

- **Ensure sectoral renewable energy targets are included in the energy mix**

The new target of 30% needs to be complemented with specific targets for different renewable technologies and different consumption sectors for 2030. Thus, reinforcing the government's commitment to the scale-up of renewable energy technologies and proposing a targeted action plan. In this regard, the energy mix proposed in REmap 2030 (Chapter 4) could be used to set a long-term vision towards the future energy mix, along with the sectoral objectives that combine energy efficiency and renewable energy deployments.

Box 4 outlines some of the guidelines provided in IRENA's report, Renewable energy target setting.

Box 4 Guidance on renewable energy target setting

Making targets mandatory; establishing targets in law is an important step in increasing their credibility and longevity.

Renewable energy targets exist at the intersection of multiple policy drivers and priorities including energy security, environmental sustainability and socio-economic benefits.

While renewable electricity targets are most widespread, heating/cooling and transport sector targets are crucial for the energy transition.

Targets send an important signal to stakeholders and investors.

Stakeholder engagement strengthens ownership and target feasibility.

Technology-specific targets can be used to support the diversification of the energy mix to increase energy security along with sustaining the development of the local value chain of selected technologies.

Targets established in absolute terms (a specific quantity of energy to be supplied) may be easier to set and monitor but targets that are relative to a moving baseline (i.e., in percentage terms) could be more effective.

Those responsible for meeting targets, as well as the means they employ to this end, require consideration.

Striking the right balance between ambition and realism is vital to the success of targets.

Effective renewable energy targets should be backed by clear strategies and specific policies.

Source: IRENA, 2015.


Photograph: Shutterstock

Challenge C: High subsidies and low tariffs

Electricity in Lebanon is highly subsidised. Therefore, the potential for future investments within the sector remains limited, resulting in high technical and non-technical losses (34%, combined) and an old fleet of power plants. With that said, low electricity tariffs discourage investment in small-scale renewable energy applications, especially within net-metering schemes.

Recommendation:

- **Reform subsides and tariffs**

While renewable energy is gaining momentum on a global scale, to further build public and private investments on the national level, increasing tariffs may encourage both public and private investments in renewable energy projects, thus substituting expensive and aged thermal generation. Furthermore, higher tariffs would allow for the proliferation of renewables through small- and medium-scale deployment.

Challenge D: Limitations of enabling schemes for small-scale RE applications

The current net metering scheme was applied following a decision of the board of directors of EDL. It allowed for consumers to reinject excess renewable energy into the national electricity grid. However, the customers cannot reinject more than the equivalent of their total annual consumption, which limits the extent of application of renewable energy to other sectors such as the commercial and industrial sectors.

Moreover, complex administrative procedures coupled with a lack of awareness between the local authorities and the security services are causing bottlenecks in project implementation at the local level.

Finally, the existing net-metering scheme does not allow for off-site installation or power wheeling and peer-to-peer energy exchange, which limits the possibility of the wider deployment of small-scale applications.

Recommendations:

- **Adopt legislation to promote distributed renewable electricity:**

The deployment of virtual net-metering may be considered, by allowing consumers to buy shares in renewable energy projects and having the income deducted from their electricity bills.

Specific schemes could be developed paving the way for peer-to-peer contracts through direct PPA, allowing the developer to sell electricity directly to specific consumers, as shown in Box 3 in the REmap case section.

Challenge E: Coupling heating and cooling technologies in a national scheme

To date, efforts to deploy renewables in the heating and cooling sector have been represented by the application of solar water heaters. Although the adopted incentive schemes have been successful, SWH installations have slowed in recent years due to the removal of incentive mechanisms previously adopted in Lebanon.

Recently, the adoption of heat pumps has increased, given their high level of energy efficiency and their ability to serve the dual purpose of heating water while cooling space. However, there is a lack of data and support programs to deploy the full potential of this technology.

Recommendation:

- **Reinstate incentives for the installation of heating and cooling**

The benefits of renewable energy are not solely in the power sector but also in the heating and cooling sector, therefore increasing the level of solar ordinance while inducing the mandatory use of SWHs (with the possibility of installing heat pumps in parallel) on all rooftops of new buildings could be considered.

As elaborated in the REmap section, subsidising heat pumps to increase competitiveness and reducing the import and/or registration taxes on electric boilers through financing with international grants will complement SWH incentives, resulting in cost reductions. Incentives for the deployment of super-efficient heat pumps may be considered, keeping in mind the synergies with the power sector and the dependence of heat pumps on the availability of power.

The country is advised, therefore, to establish a data bank for heat pump market potential and create support programs to incentivise investments.

RESOURCES, TECHNOLOGY AND INFRASTRUCTURE

Despite ample renewable energy resources – particularly solar and wind – several challenges to the deployment of renewables exist in the grid system, at both the transmission and distribution levels. IRENA has found that addressing grid service concerns is possible by conducting grid impact assessments, reinforcing transmission infrastructure and introducing certification schemes.

Challenge A: Concerns over grid stability and capacity constraints

In 2017, the UNDP CEDRO project developed a wind grid interconnection guide for Lebanon (CEDRO, 2017), in which frequency readings of the Lebanese grid were published. These readings showed very high instabilities not only on the lower end where it reached 48 Hz but also on the higher end of the spectrum where it reached close to 52 Hz.

When dealing with large-scale projects, instability becomes a problem, particularly on the technical side where it causes major issues for renewable energy plants when attempting to synchronise with the national grid. The frequency variations are the key parameters to shed loads based on a pre-assigned priority grid where the dispatching centre begins to shed loads from the lowest priority and up until the frequency stabilises.

As Figure 13 shows, the transmission network shows weak zones where it is not sufficiently developed to handle power and frequency fluctuations from renewable energy generation, especially in the south-east or heavily congested areas like Mount Lebanon. This situation constrains the connection of large-scale renewable energy projects.

Moreover, regional instability has deprived the Lebanese grid of interconnection to the regional network, thus forcing additional measures to maintain stability.

Based on the wind atlas for Lebanon (GH, 2011) or solar irradiation measurements, the highest potential for wind generation is concentrated in the Akkar and Bekaa-Hermel regions, which are endowed with a significantly high solar irradiation estimated at 20% above other regions. These regions suffer from an underdeveloped transmission grid, especially on the medium voltage level where most of the substations are saturated or the network is not developed. This is essentially due to lower population density and weak economic development. However, a new overhead transmission line of 66kV is under construction with an expected service date in 2020, pertaining to a capacity of 145 MW.

Transmission investment needs were addressed in the 2013 master plan that was completely executed, and updated with amendments in 2017 and approved by the then government, where the major project focus was on developing both the north and south loops of Beirut, coupled with several investments in the transmission infrastructure of other regions in the country.

The size of PV farms allows for the advantage of direct connection to the distribution sector without going through the transmission network, hence saving on transmission losses and acting as a back-up load replacing bulky generators. That said, the extension of the low-voltage network to include future medium-scale PV farms being evaluated currently within the scope of the 180 MW of PV farms may lead to a reduction in losses.

Recommendations:

- **Conduct a complete grid impact assessment**

Global best practices find that grid impact assessments on the national level may assist in overcoming the technical limitations to the integration of renewable energy in the grid and reinforce long-term planning to match the expected high levels of renewable energy penetration in 2030, including grid reinforcement. Moreover, dynamic stability studies are needed to overcome grid challenges as highlighted in the REmap section, in addition to the outcomes of IRENA's 2017 report, Planning for the renewable future: Long-term modelling and tools to expand variable renewable power in emerging economies.

Specialised system studies may be conducted (IRENA, 2017c), including:

• An assessment of the renewable energy carrying capacity of the Lebanese transmission and distribution grid under different geographical zones of interest. Such a study would also present the current picture of the grid's inertial strength and flexibility limits, and identify areas of reinforcement in terms of advancing grid code, ancillary service regime and grid expansion priorities.

• A long-term generation adequacy study, appropriately modelling committed renewable energy resources (an important aspect often ignored in status quo planning processes). The analysis could be performed for 2025 and 2030. Such an analysis would also inform policy making to better incentivise future energy sector investments.

The aforementioned assessment would help EDL in the realistic review of the ability of renewables to meet the country's power demand. This would also augment the planning processes at EDL whereby, in addition to transmission and generation planning, EDL can specifically plan for the flexibility and stability aspects of the grid.

Moreover, power and frequency fluctuations can be addressed by adding renewable energy plus storage systems, as well as pumped hydro systems, which will help harmonise the power output (Roy, 2019). This was one of the main reasons behind the expression of interest for PV with storage that was launched by the MEW and the LCEC. IRENA finds that the introduction of battery storage technologies can lead to multiple benefits, including enhancing grid stability, addressing curtailment concerns, along with the factors described in Box 2 of the REmap section.

As for hydropower concessions, the country could re-evaluate existing agreements with the Litani River Authority and new IPPs to include reserve capacity for frequency control and ancillary services.

- **Reinforce the transmission grid**

As highlighted in the REmap section, implementation of the existing master plan is highly recommended to ensure the full deployment and expansion of the electricity grid in the various parts of Lebanon.

It may result in an increase in interconnection capacity with neighbouring countries to include easy energy flow, successful synchronisation, and increased capacity that will allow higher levels of penetration of renewables and guarantee grid stability.

- **Deploy smart meters**

As a first step for the full deployment of smart grids, smart meters could be deployed at the distribution level to ease the connections of distributed RE projects. Advanced smart charging, as described in Box 2 in the REmap section, would allow for a more successful integration of EVs by mitigating the peak created by EVs under uncontrolled charging.

- **Strengthening human resources through capacity building**

The socio-economic dimension of renewable energy is critically important for emerging economies looking to maximise the benefits from the transition in terms of job creation and local value creation. Since the first of renewable energy projects in Lebanon, EDL has assigned a dedicated taskforce to oversee renewable energy power generation.

Available human resources must be fully utilised and current industrial policies leveraged for development and training, aiming to continue building up the necessary skills sets.

Challenge B: Quality standards for off-grid applications

A lack of certification and standardisation of distributed and off-grid solar systems in the local Lebanese market.

Recommendation:

- **Complete the set of standards**

IRENA finds that minimum-quality-specific technical requirements for different applications (household PV/industries/solar pumping/solar street lighting/community-led solar systems/micro grid systems) lead to ample benefits. Lebanon could integrate capacity building and skills training for different technologies, including solar and wind, and ideally adopt a national certification scheme for the design and installation of renewable energies.

FINANCING AND THE ROLE OF THE PRIVATE SECTOR

Several financing incentives have been deployed to encourage renewable energy investments. Despite the strong presence of international finance institutions and favourable loan schemes such as the NEEREA, the Lebanon Energy Efficiency and Renewable Energy Finance Facility (LEEREFF) and the Green Economy Financing Facility (GEFF) burdensome administrative procedures exist that need to be addressed for both large-scale and small-scale applications in order to achieve a successful allocation of risks.

Challenge A: Limited access to risk coverage instruments

EDL's creditworthiness constitutes a major challenge due to low electricity tariffs and high subsidies reflecting strong off-taker risk. To help in addressing this risk, the first PPAs positioned the MEW as the main signatory, while EDL was the accessor through a letter of credit signed by the central bank of Lebanon.

Limited access to guarantees by the MoF or private guarantors restricts developers' access to viable financing. Considerable land area in the regions of Akkar, Hermel and Bekaa – with the highest solar and wind potential – do not have clear ownership licenses, creating a major challenge to the development of large-scale projects in these regions, as project developers are responsible for land acquisition.

Renewables cut costs, reduce emissions and bring socio-economic benefits

Recommendation:

- **Consider measures to facilitate development and access to financing and risk mitigation schemes**

The government may consider options to improve the creditworthiness of EDL by considering specific measures at existing electricity tariff and subsidy levels.

The replication of lessons learned by adopting standardised PPA solutions may allow for easier access to different guarantee schemes. In this context, IRENA's recently launched Open Solar Contracts – which provide the necessary contractual templates required for the bidding process, including the PPAs for solar projects – offer a useful source of information for developing standardised contractual templates or improving existing ones (IRENA, 2018); see Box 5.

The government could also consider the introduction of guarantees to back up the PPAs. One option would be the establishment of a fund to guarantee renewable energy projects, possibly with the support of international financing institutions (IFIs). This can help mitigate risks beyond those to the off-taker, such as those related to obtaining licenses.

Given that risk mitigation instruments are not easy to identify or obtain. IRENA has launched an online service for developers, lenders and investors to identify providers of risk mitigation instruments (RMIs), including guarantees that developers can access through an online matchmaking service – Climate Investment Platform (CIP). Moreover, IFIs can gradually move away from providing (concessionary) loans toward blended finance (public–private co-financing trades) and risk mitigation solutions to mobilise the local private sector rather than replace it.


Photograph: Shutterstock

Box 5 Open solar contracts

The energy sector today has a legacy of predominantly large and technically complex power generation projects. Due to their highly intricate transaction structures, these projects required customised and complex legal and financial solutions, which have been inherited by renewables. This has resulted in high transaction costs and prolonged project development timelines, hindering further capacity growth, particularly in small to medium-scale renewable energy projects. Therefore, redesigning prevailing market practices in project development and finance emerges as a pressing need and reforming the overly complicated contractual framework needs to be a priority.

In response, IRENA and TWI have jointly launched an initiative to simplify and streamline the contractual framework for solar power to unlock greater investments globally. This initiative (Open Solar Contracts), which is supported by multiple top-tier law firms, provides a standardised contractual documentation solution that is freely and publicly available and designed to be universally applicable.

The initiative presents templates for six core contracts:

1. Implementation agreement	4. Installation agreement
2. PPA	5. O&M agreement
3. Supply agreement	6. Finance term sheet

The work on the contracts was supported by the review of specific model clauses in order to deal with cross-cutting matters in a consistent way and to reduce complexity. These include:

1. Governing law	4. Corruption and sanction
2. Dispute resolution	5. Force majeure
3. Grid connection principles	

The resulting package of contract templates offers a consistent legal documentation solution. The templates are intended to be used in conjunction with one another to ensure that the scope of work and risks are appropriately allocated.

The initiative aims to decrease transaction costs, shorten project development timelines and establish a balanced risk allocation between the public and private parties. The initiative also aims to facilitate due diligence processes by financiers and lay the groundwork for project aggregation and securitisation. These would eventually support the rapid and widespread scale-up of solar power at the level required.

The contracts are available for review at:
http://opensolarcontracts.org

Challenge B: Limited interest from local banks to fund small-scale distributed projects

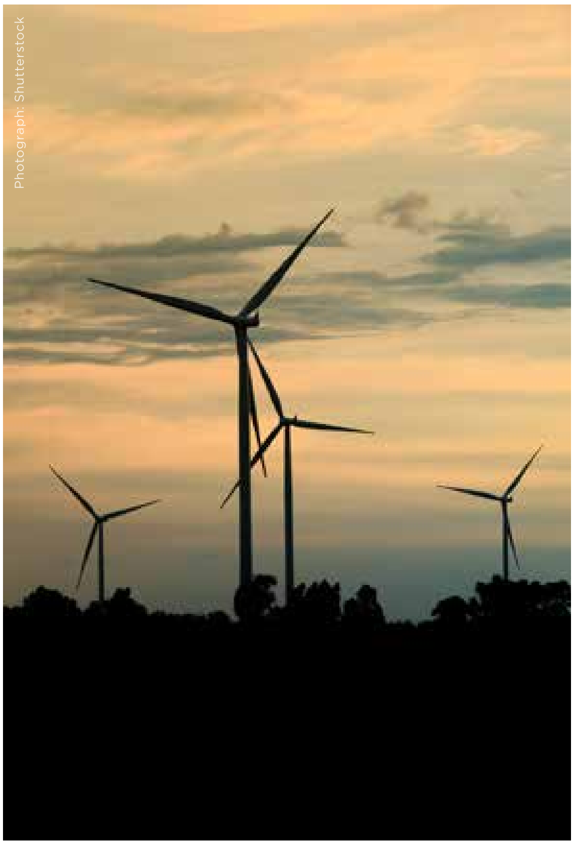
Despite the increasing size of renewable energy projects in Lebanon, Lebanese commercial banks (LCBs) are losing interest in financing relatively small projects due to high transaction costs, limiting the widespread use of decentralised applications in the residential sector.

Recommendations:

- **Bundle renewable energy projects**

LCBs could also consider bundling of smaller-size renewable energy projects to achieve the required scale, thus reducing transaction costs while bolstering financial institutions confidence in projects and decreasing risks. However, standardisation is needed as a pre-condition for the bundling of renewable energy projects.

- Once projects are standardised and aggregated (e.g. in a green bond), they could potentially be attractive to non-bank investors as well, such as institutional investors (insurance companies, pension plans, sovereign wealth funds, etc.) which prefer large scale investments through investment vehicles such as funds and bonds. IFIs active in this region can also help create (and provide first capital) for such investment vehicles, to attract more financiers to the renewables sector.


Photograph: Shutterstock

Challenge C: Land acquisition limitations and complex administrative processes

Currently, all bids being launched by the MEW and the LCEC allocate responsibility for securing the land to project developers, inducing additional risks pertaining to grid interconnection and resource availability.

The documentation requirements for bids and EOIs are complex and time-consuming, and the list of required documentation is not clear. This does not help to attract domestic and foreign investors into the sector. Moreover, bidders do not have access to a template of the resulting PPA contract, thereby increasing the variables and perceived risk.

Recommendations:

- **Consider conducting land-specific auctions**

So far, developers have had to take over the responsibility for securing the land, introducing additional risks related to grid interconnection and resource assessment. Some studies have been conducted to identify suitable sites in terms of land ownership (mostly publicly owned), resource availability and proximity to the grid (such as A. Berjawi et al., 2017 and AUB, 2019 as highlighted in S.3.c). Such plots could be considered in future rounds, as the allocation of costs and the risks associated with land to the government has the potential to significantly reduce the prices resulting from auctions.

Across the different auction design elements, policy makers may consider the inherent trade-offs between potentially the most cost-effective outcome and other objectives including: ensuring projects are delivered on time, integrating higher shares of variable renewable energy, and supporting a just and inclusive energy transition (IRENA, 2019b). For further information on auction design, please see Annex 1.

- **Standardise requirements in the bidding process**

IRENA suggests including standardised documentation requirements and a transparent portal outlining the details of auctions to encourage bidders.

Standardised environmental practices for all the different renewable energy technologies could be adopted by working with international development organisations to create a 'bird migration protocol' that would meet all requirements for obtaining loans by IFIs.

Challenge D: Inadequate governing framework for hydropower concessions

Since the concessions for large-scale hydropower installations were formed prior to the establishment of EDL, there are two main challenges: first, the administrative framework needs to be revisited; second, the tariffs are not attractive enough to incentivise efficient production – apart from the Litani River Authority, which was changed from USD 0.03 to 0.04 per kWh in 2017 and remains relatively low.

Recommendations:

- **Develop a new administrative framework and re-evaluate the tariffs**

The existing framework governing water concessions has been in place since the 1900s and ends in the period 2020–2025, therefore a new framework adapted to the current context, coupled with a re-evaluation of the agreements of existing hydropower concessions to include higher tariffs may motivate the concessions to invest in maintaining and upgrading existing hydropower stations.

- **Consider the broader benefits of sustainable hydro development**

The construction of dams based on sustainable practices can provide value to Lebanon not only for electricity generation but also other uses such as contributions to irrigation as well as flood and draught control. During planning efforts, proper quantification of the value of hydro dams that account for these multiple uses of water contribute to the enabling of the development of hydropower with dams in Lebanon – as long as one ensures that all hydro projects are planned and developed according to the best social–environmental practices.


Photograph: Shutterstock

Annex 1: Auction design and key factors influencing price results

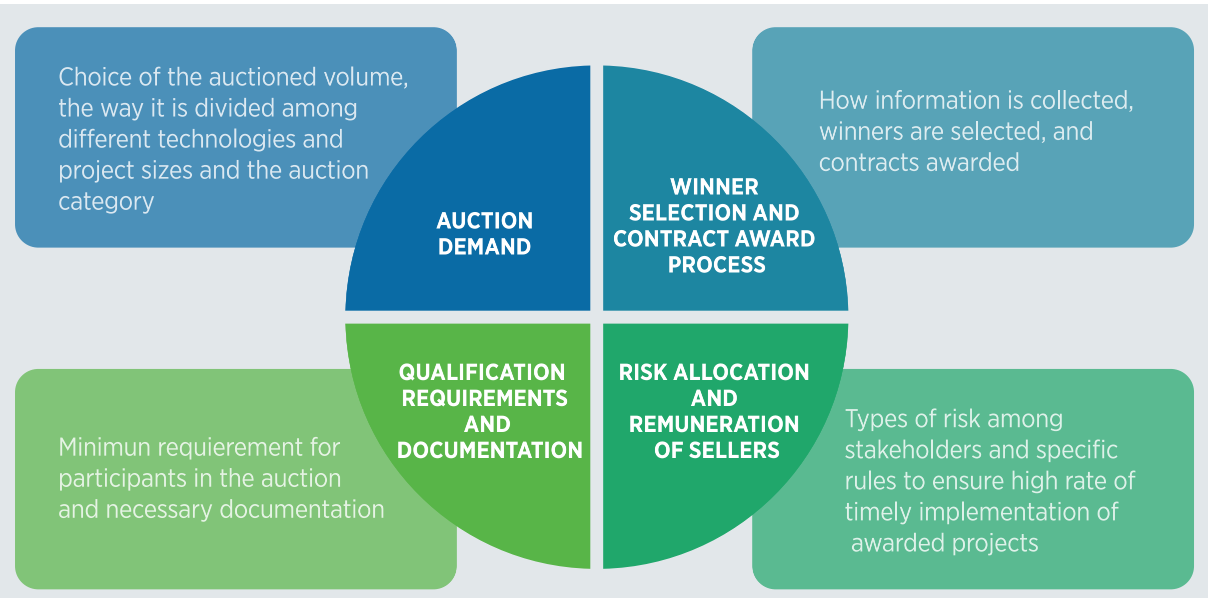
IRENA's 2015 report Renewable energy auctions: A guide to design presented a framework for analysing auctions. The framework classified design elements into four main categories: auction demand; qualification requirements; winner selection; and sellers' liabilities (IRENA, 2015). The framework was updated in IRENA's latest report, Renewable energy auctions: Status and trends beyond price, reflecting developments and lessons learned in the dynamic renewable energy sector in the intervening years. This is presented in Figure 44.

Decisions made in the 'auction demand' category determine what is to be procured, and under what conditions. Crucial demand-side considerations include: 1) the product to be auctioned (energy, capacity, green certificates, transmission lines, financial transmission rights, ancillary services or a mix); 2) whether and how the total demand is to be split among different products (technologies, zones or other breakdowns); 3) the volume of the product to be auctioned and the lower and upper limits on the project size; 4) whether a pre-set auction schedule will be adopted and, if so, the schedule of committed future auctions; and 5) responsibility for demand-side commitments, which includes evaluating the factors that assure project developers of the off-taker's creditworthiness.

In defining the auction's demand, the ambition for a greater role of renewables in the energy mix must be weighed against cost-effectiveness. When the objective is to develop a particular technology, a technology-specific auction can be selected. If the goal is minimising costs, a technology-neutral auction can be introduced, allowing competition between technologies (e.g. in Brazil). When the objective is to meet urgent capacity needs while retaining flexibility in holding auctions, the total volume can be auctioned at once, through a standalone auction. If the objective is to further enhance investors' confidence in a more cost-effective outcome, the total volume auctioned can be divided into different rounds in a systematic auctioning scheme.

The category of 'qualification requirements and documentation' determines which suppliers will be eligible to participate in an auction and includes both the conditions participants must meet and the documentation they must provide prior to the bidding stage. Such requirements commonly relate to: 1) documentation to confirm that the firm has the capacity to develop the project; 2) site-specific documentation; 3) technical requirements for the project; and 4) instruments to promote socio-economic development.

Figure 44: IRENA's updated auction design framework



Source: IRENA, 2019b

Qualification requirements are key determinants of the competition in the auction and the prices offered by developers. If requirements in terms of permitting and documentation processes are too demanding, the transaction costs incurred by developers can be reflected in higher prices. Transaction costs can be reduced through site- or project-specific auctions where the government (or another entity) takes on the responsibility of site selection, resource and impact assessments, grid connection and obtaining necessary permits (e.g. in Denmark, Germany and the Netherlands). Moreover, while the requirement for an extensive track record in the field can help ensure timely project completion, it may also limit the participation to traditional, large players in the sector, which in turn affects the overall development of the sector.

Qualification requirements can also be designed to meet broader development goals related to domestic industry development and job creation (e.g. in South Africa and China).

In the 'winner selection and contract award' process, bidding and clearing rules are applied and contracts are awarded to the winner(s). The subcategories include: 1) the formal bidding procedures, which set forth how supply-side information is collected; 2) minimum competition requirements, including provisions to ensure participation by multiple, competing bidders; 3) winner selection criteria, dictating how bids will be ranked and winners selected; 4) the clearing mechanism, which defines rules for allocating contracts based on accepted bids; and 5) payment to the winner.

The winner selection process is at the heart of the auction. The criteria for selection, ceiling prices and limits on project size can significantly impact price outcomes, with the possibility of facing the following trade-offs. While a simple winner selection process based solely on the price can improve cost competitiveness, other objectives can be achieved by incorporating non-monetary criteria, such as socio-economic benefits and project location (e.g. in Mexico). In addition, when the main objective is to ensure cost effectiveness, a low ceiling price can be set, above which bids are not considered; however, there is a risk that a sub-optimal amount of renewable energy will be contracted as a result, as such a low ceiling price lead to the rejection of some reasonable bids.

A limit on the project size or on the volume that can be won by one bidder also impacts the price. Such measures were put in place in Zambia to diversify the portfolio of generators and reduce risks in case projects do not materialise. Auctions that have no limit on project size can benefit from economies of scale, as in the case of Dubai and Abu Dhabi in the United Arab Emirates, where 800 and 1 170 MW of solar was contracted, respectively, at record-breaking prices in 2014 and 2016 respectively.

Procedures in the category of 'risk allocation and remuneration of sellers' define how risks (financial, production and others) are allocated among stakeholders (bidders, auctioneers, off-takers, financial institutions, consumers, etc.). These risks, responsibilities and obligations should be spelled out in auction documents. This critical design element involves: 1) commitment bonds (typically a bid bond and a construction bond) and a schedule for contract signature and commencement of commercial operations; 2) production and financial risks (associated with inflation, currency fluctuations, market prices and production hazards); 3) quantity-based liabilities, including settlement rules and penalties for underperformance; and 4) penalties for delays and underbuilding.

In determining the sellers' liabilities in the power purchase agreement, there are various ways to allocate financial, operational and production risks between the project developer, the auctioneer and the off-taker. Auction design features can limit the developers' risks resulting in lower prices, but these risks would then be passed on to the off-taker. Currency, inflation and production risks can be reduced through auction design (e.g. in Chile). In addition, liabilities can be reduced to encourage participation and increase competition, but at the risk of facing project delays or underproduction. Investor liabilities involve commitment to contract signing and project completion as well as compliance rules and penalties.

These are important measures to ensure that projects are developed on schedule to meet the capacity needs of the power sector. However, if these measures are too strict, competition in the auction will be reduced, leading to higher prices. There are innovative ways to address these trade-offs, as in the case of Germany, where bidders with building permits saw their bid bond and completion bond requirements reduced by almost half.

Annex 2: Assumptions behind the levelised cost of electricity (LCOE)

The LCOE for renewables is mainly driven by the capital expenditure (CAPEX) that is initially taken based on current average local market prices. The CAPEX for renewables is then projected to 2030 by multiplying its current values for each technology by the respective percentage CAPEX variation between 2016 and 2030, as per IRENA estimates. CAPEX for hydro is an exception and is taken as per the prices estimated in the corresponding MEW EOI. The OPEX is taken as a percentage of the CAPEX as per IRENA estimates for each technology. LCOEs are then computed for different discount rates: 7% to reflect good conditions, 10% to reflect fair conditions, and 13% to reflect poor conditions.

The worst case is assumed to correspond to the most expensive LCOE for renewables – assumed to be the one expected today in the Lebanese market. The best case is assumed to correspond to the multiplication of the current expected LCOE in Lebanon by the percentage variation between the current LCOE, as per IRENA values, and the cheapest LCOE for renewables obtained using the 7% discount rate. The average case is the mid-value between the two extremes, while the overall results are summarised in Table 15.

The LCOE for natural gas is mainly driven by the OPEX. The first variable considered for computing the LCOE for conventional generation is the discount rate, taken as the same as for renewables, assuming market discount rates are similar for conventional and renewable energy projects. The second variable is the price of natural gas, taken as per IRENA estimates for 2030: USD 5.2/MMBTU, USD 6.9/MMBTU, and USD 8.5/MMBTU to reflect cheap, moderate and expensive gas prices. The overall results are shown in Table 16; Table 17 shows the overall savings under worst-case (LCOE1, cost1), mid-case (LCOE2, cost2) and best-case (LCOE3, cost3) scenarios obtained for the different combinations of the LCOEs for renewable and conventional technologies.

The worst-case scenario corresponds to the cheapest LCOE for conventional and most expensive LCOE for renewables. The best-case scenario corresponds to the cheapest LCOE for renewables and most expensive LCOE for conventional, while the average case corresponds to the mid-values for LCOEs. The total savings correspond in each case to the difference between the overall cost of energy in the reference case and the overall cost of energy in the REmap case.

Table 15: Summary of estimated LCOE for renewables in 2030

RES – technology	LCOE summary (USD ¢/KWh)		
	Lower bound	Mid-range	Upper bound
Solar PV – utility	2.44	4.47	6.50
Wind – onshore	6.93	8.27	9.60
Hydro	2.65	5.33	8.00
Biogas	1.00	4.55	8.10

Table 16: Summary of LCOE for conventional sources

LCOE summary (USD ¢/KWh) – conventional plants (natural gas)		
Lower bound	Mid-range	Upper bound
9.28	10.75	12.22

Table 17: Summary of savings in the power sector: Reference case and REmap case[15]

REF 2030	Capacity (MW)	LCOE1 (USD ¢/KWh)	LCOE2 (USD ¢/KWh)	LCOE3 (USD ¢/KWh)	Generation (GWh)	Cost1 (USD m)	Cost2 (USD m)	Cost3 (USD m)
Natural gas	4 909	9.29	10.76	12.23	27 432	2 548	2 951	3 355
Wind	626	9.60	8.27	6.93	1 817	174	150	126
Hydro	601	8.00	5.33	2.65	1 749	140	93	46
Solar PV[16]	1 030	6.50	4.47	2.44	1 789	116	80	44
Biogas	8	8.10	4.55	1.00	59	5	3	1
Estimated total energy cost (USD million)						2 984	3 277	3 571
REmap 2030	**Capacity (MW)**	**LCOE1 (USD ¢/KWh)**	**LCOE2 (USD ¢/KWh)**	**LCOE3 (USD ¢/KWh)**	**Generation (GWh)**	**Cost1 (USD m)**	**Cost2 (USD m)**	**Cost3 (USD m)**
Natural Gas	4 909	9.29	10.76	12.23	23 393	2 173	2 517	2 861
Wind	1 000	9.60	8.27	6.93	2 655	255	219	184
Hydro	601	8.00	5.33	2.65	1 749	140	93	46
Solar PV[17]	2 500	6.50	4.47	2.44	4 342	282	194	106
Biogas	13	8.10	4.55	1.00	99	8	5	1
Estimated total energy cost (USD million)						2 858	3 028	3 198
Estimated total energy cost savings (USD million)						**126**	**249**	**373**

15 Results are rounded to the nearest integer.
16 Includes centralised solar PV only.
17 Includes centralised solar PV only.

Annex 3: Values considered for each sector

Sectors*	Base year (2014)	Reference case (2030)	REmap Case (2030)
Buildings sector			
Space cooling	N/A	• Yearly growth for electricity consumed: 3.46%	N/A
Space heating	N/A	• Yearly growth for oil and gas consumed: 3% • Yearly growth for electricity consumed: 3.46%	• 25% of the energy consumed from an oil-based source for space heating is replaced by heat pumps. • Assuming a boiler efficiency of 90% and heat pump COP 3.5. • 10% of the electrical energy used for space heating from electric heaters in existing buildings and 75% of the electrical energy consumed for space heating from electric heaters in new buildings replaced by heat pumps. • Assuming that the electrical energy consumed in buildings for space heating is from electric heaters.
Water heating	N/A	• Yearly growth for oil consumed: 3% • Yearly growth for electricity consumed: 3.46% • Yearly growth for solar thermal energy consumed: 9.4% • Yearly growth for geothermal energy consumed: 19%	• 10% of the electricity consumed for water heating in existing buildings and 75% of the electricity consumed for water heating in new buildings replaced by heat pumps. • Assuming that the electrical energy consumed in buildings for water heating is from electric boilers. • 25% of the energy consumed from an oil-based source for water heating, assuming all of it is via conventional boilers, is replaced by solar water heaters in 2030. Assuming 90% boiler efficiency.
Cooking	N/A	• Yearly growth for gas consumed: 3%	• 10% of the energy consumed from LPG for cooking in existing buildings and 5% of the energy consumed from LPG for cooking in new buildings replaced by electric cooking. • Percentages are arbitrary and chosen in a way so as not to increase the overall demand for electricity beyond its overall value in the reference case. • Assuming 35% efficiency for LPG cooking. • Assuming 60% efficiency for electric cooking.
Lighting	N/A	• Yearly growth for electricity consumed: 3.46%	N/A
Appliances	N/A	• Yearly growth for electricity consumed: 3.46%	N/A
Industrial sector			
All except cement industries	N/A	• Yearly growth for oil and electricity consumed: 0.1%	N/A
Cement industries	• Cement delivered is locally manufactured. • 300 MJ/ton of cement as electricity needed. • 3 325 MJ/ton of cement as thermal energy needed, reported under oil products.	• Yearly growth for cement delivered: 2.42% • The tons of delivered cement in 2014 is the average of the values delivered in 2013 and 2015.	• Assuming cement delivered is locally manufactured. • Assuming 300 MJ/ton of cement as electricity needed. • Assuming 3 325 MJ/ton of cement as thermal energy needed, reported under oil products.

Sectors*	Base year (2014)	Reference case (2030)	REmap Case (2030)
Transport sector			
Road passenger vehicles	N/A	N/A	• 3% of the projected passenger kilometre in the reference case 2030 supplied from electric vehicles. • Assuming occupancy rate 1.82 passengers per car. • Assuming fuel economy 11.16 L/100 km. • 5% of the projected volume of oil consumed in the Reference case 2030 remaining after the introduction of EVs supplied from bioethanol. • Percentages are arbitrary and chosen in a way so as not to increase the overall demand for electricity beyond its overall value in the reference case.
Road (others)**	N/A	N/A	N/A
Power sector* **			
Utility	N/A	• Electricity demand for 2030 estimated starting from 2017 value. • 3% growth in demand until 2020, 8% drop in 2020, and 3% growth from 2020 to 2030. • Energy generated by the utility in 2030 = 33 500 GWh, assuming 24/7 electricity supply from the utility and 8% T&D losses. • Assuming full shift towards natural gas. • Assuming that the renewables are given a priority for generation. • Assuming overall weighted efficiency of 39.18% for CCGT and OCGT plants assuming they are running on natural gas. • Assuming 61% of installed conventional capacity is CCGT running on natural gas at an efficiency of 45%. • Assuming 39% of installed conventional capacity is OCGT running on natural gas at an efficiency of 31%.	• The Installed capacities for CSP and hydro assumed to remain as proposed by the corresponding studies in the reference case 2030. Only wind and solar PV were promoted to reach the 30% target of the electricity consumed in 2030. • Assuming LCOE for solar PV farms is cheaper than the LCOE for wind farms. • Around 375 MW of additional wind farm is arbitrarily proposed to keep a diversified mix. The rest of the capacity needed to generate the renewable energy required to reach the 30% target is promoted from solar PV assuming a cheaper LCOE and a relatively easier integration process. • Assuming the electricity generated in the power sector is equal to the electricity demand + 8% T&D losses. Therefore, 30% of the electricity generated in the power sector would be equivalent to 30% of the energy consumed. • Assuming that the renewables are given a priority for generation, the rest of the electricity that needs to be generated to meet the demand is supplied from OCGT and CCGT plants running on natural gas. • The remaining assumptions are taken as per the reference case 2030.
Autoproducers	• Assuming autoproducers are mainly diesel generators. • Assuming autoproducer consumption rate is 3.8 L/KWh. • Assuming 38.29 MJ/L energy content of diesel.	• Diesel autoproducers assumed to be phased out in 2030. • RES autoproducers assumed to be rooftop decentralised solar PV: 150 MW.	• Diesel autoproducers assumed to be phased out in 2030. • RES autoproducers assumed to be rooftop decentralised solar PV: 500 MW, assuming the market is able to take it. Zero cost assumed when considering investments and savings in the REmap case.

*N/A: No assumptions taken, data reported and used as per corresponding source.
**Heavy duty vehicles, light duty vehicles, buses and motorcycles.
***RES Autoproducers assumed to be decentralised rooftop solar PV.

REFERENCES

A. Berjawi, S.N., et al. (2017) "Assessing solar PV's potential in Lebanon", Beirut.

American University of Beirut (AUB) (2019). Bankability of a large-scale solar plant in Tfail Lebanon, Beirut, Lebanon, www.aub.edu.lb/ifi/Documents/publications/policy_briefs/2018-2019/20190502_bankability_large_scale_solar_power_plant_tfail_lebanon.pdf

Bassil, G. (2010), "Policy paper for the electricity sector", Ministry of Energy and Water, Beirut.

CEDRO (2017), "Wind energy grid interconnection code for Lebanon",Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon, UNDP, Beirut.

CEDRO (2013), "Hydro-power from non-river sources", Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon, UNDP, Beirut.

DREG (Small Decentralized Renewable Energy Power Generation Project) (2017), "2017 Solar PV status report for Lebanon", UNDP, Beirut.

Electricité du Liban (EDL) (2018), Annual report on the electricity sector bottle necks and factors of success for 2017, Beirut, www.edl.gov.lb/decisions.php?did=3

EDL (2019), Interview provided to LCEC.

Garrad Hassan (2011), "The national wind atlas for Lebanon", UNDP-CEDRO, Beirut.

IEA (2019), "Data and statistics", www.iea.org/statistics (viewed in November 2019).

IRENA (n.d.), *Global Atlas for Renewable Energy*, DTU Global Wind Dataset 1 km onshore wind speed at 200 metres height", International Renewable Energy Agency, Abu Dhabi.

IRENA (n.d.), *Global Atlas for Renewable Energy*, "World Bank 1km Global Horizontal Irradiation",International Renewable Energy Agency, Abu Dhabi.

IRENA (2019a), "Renewable power generation costs in 2018", International Renewable Energy Agency, International Renewable Energy Agency, Abu Dhabi.

IRENA (2019b), "Renewable energy auctions: Status and trends beyond price".

IRENA (2018), Open Solar Contacts, https://opensolarcontracts.org/#contracts.

IRENA (2017a), "Renewable energy auctions: Analysing 2016", International Renewable Energy Agency, Abu Dhabi.

IRENA (2017b), "Renewable energy benefits: Leveraging local capacity for onshore wind", International Renewable Energy Agency, Abu Dhabi.

IRENA (2017c), "Planning for the renewable future: Long-term modelling and tools to expand variable renewable power in emerging economies", International Renewable Energy Agency, Abu Dhabi.

IRENA (2017d), "Renewable energy benefits: Leveraging local capacity for solar PV", International Renewable Energy Agency, Abu Dhabi.

IRENA (2015), "Renewable Energy Target Setting", International Renewable Energy Agency, Abu Dhabi.

LCEC (Lebanese Centre for Energy Conservation) (2019a), Directorate General of Oil provided by LCEC, Interview.

LCEC (2019b), Data provided by LCEC; unpublished.

LCEC (2019c), "The Evolution of the Solar Water Heaters Market in Lebanon, 2012-2017 and Beyond", LCEC.

LCEC (2019d), "2018 Solar PV Status Report", LCEC.

LCEC (2018), "The first energy indicators report of the Republic of Lebanon", Beirut: MEW.

LCEC (2016), "National renewable action plan for Lebanon, 2016–2020", LCEC.

LCEC (2010), "National energy efficiency action plan, 2011–2015", Beirut: LCEC.

MEW (2019a), Announcement by the Lebanese Ministry of Energy and Water (MEW) at the International Beirut Energy Forum 2019, 25-27 September 2019.

MEW (2019b), Power plant capacity and performance data (provided by Ministry of Energy and Water, Lebanon), 2019.

MEW (2019c), "Update of the electricity reform paper", MEW, Beirut.

Roy, P.K.S. (2019), "Investigations into best cost battery-supercapacitor hybrid energy storage system for a utility scale PV array", Journal of energy storage, Volume 22, 50–59.

Sogreah-Artelia (2012), "Schema Directeur Hydro-Electrique du Liban", MEW, Beirut.

UNDP (United Nations Development Programme) (2016), LCRP 2017–2020, UNDP, Beirut.

World Bank (2019a), "World Bank Data, Population", February 12, https://data.worldbank.org/indicator/SP.POP.TOTL?end=2017&locations=LB&start=2000 (viewed in November 2019).

World Bank (2019b), "World Bank GDP", February 12, https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2017&locations=LB&start=2000 (viewed in November 2019).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